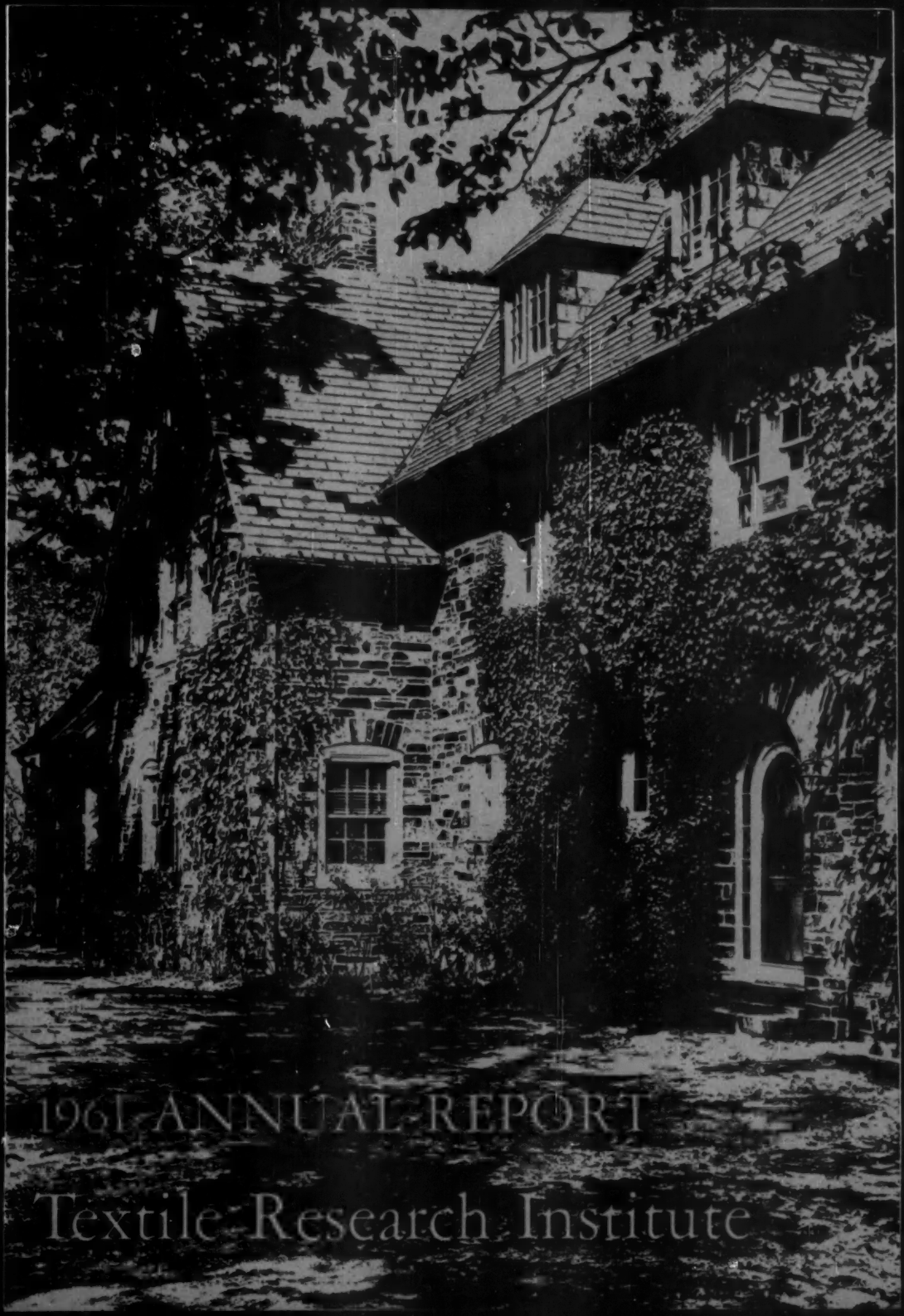

1961 ANNUAL REPORT
Textile Research Institute

1961 ANNUAL REPORT

Textile Research Institute

PRINCETON, NEW JERSEY

Contents

STATE OF THE INSTITUTE	3
TRI OFFICERS AND TRUSTEES	8
COMMITTEES	9
RESEARCH	15
GRADUATE EDUCATION	36
DISSEMINATION FUNCTIONS	41
APPENDIX	43

RUSSELL W. PETERSON
Chairman of the Board

J. H. DILLON
President

State of the Institute

Textile Research Institute in 1961 continued to make progress along its three chosen avenues of effort—basic research, graduate training of scientists, and diffusion of knowledge.

The research effort has been fruitful, as may be judged by scientific papers presented and published. It is, by the way, gratifying to note that several United States and foreign patents were granted to TRI scientists in 1961, based on work of earlier years. Numerous requests for TRI scientists to present their findings before the research groups of Institute Members suggest that the current program is soundly conceived and is yielding important, interesting results. Renewal of two group-supported research projects, *Fatigue of Textile Fibers* and *Resilience of Chemically Modified Cottons,* with new, stimulating approaches, indicated continued Member participation.

The TRI research group was strengthened and greatly improved in balance by the addition of several able postdoctoral fellows. On the basis of their work thus far, it is probable that all of them will be invited to do another year of postdoctoral research at TRI and it is possible that one or more of them will be offered permanent staff positions.

The decision of Dr. Joseph H. Dusenbury to accept a research post with a Member organization early in 1961 made necessary a redistribution of research assignments. Our three Associate Research Directors, W. James Lyons, Ludwig Rebenfeld, and Robert F. Schwenker, Jr., are to be congratulated on their assumption of additional responsibilities with no apparent change in stride. They would insist, however, that this was possible only by virtue of the versatility and cooperativeness of the senior and junior scientists who constitute their research groups. It is a pleasure to acknowledge the contributions of all our TRI researchers, as well as those of the supporting staff—shop, computation, maintenance, etc. Likewise, the valuable counsel of the Research Advisory Committee and our various project advisory committees, made up of busy scientists of industry, government, and academic institutions, is gratefully acknowledged.

The TRI program of graduate education, conducted cooperatively with Princeton University, continued to function effectively throughout 1961. TRI Research Fellows have measured up as graduate students of Princeton University, and their doctoral research at TRI has been of a quality comparable to that of their predecessors, who now number over forty Princeton Ph.D.'s plus several master's degree graduates. The fact that six of our predoctoral Research Fellows were supported by grants from Member organizations in 1961 indicates growing appreciation of the importance of this facet of the TRI program. Credit for this situation must be shared by our enthusiastic group of graduate students; our Research Associates: Professors Kauzmann, Pacsu, Suppiger, Taylor, Tobolsky, and Whitwell; Dr. Rebenfeld, who has administered this program; and a number of senior staff members who have been generous with advice in their various specialties.

Textile Research Journal has continued to play the principal role in TRI's program of diffusion of knowledge. TRI Members may take justifiable pride in their support of the Journal from its inception in 1945 to its present internationally recognized position as a means for disseminating textile research information. No longer is it necessary to "promote" the Journal as a proper medium of publication for there is now a substantial inflow of scientific papers. It is apparent that the early efforts of Julian S. Jacobs, the Journal's first editor, have borne fruit which indeed nourishes textile research throughout the world. Dr. R. K. Toner, who took over the post of Editor in 1959, has maintained the quality of *Textile Research Journal,* with the expert assistance of our Production Editor, Mrs. Dorothy Hollmann. It is good to report that the Journal is "in the black" for the third successive year.

TRI Seminars constitute another dissemination effort. Growing attendance at these informal meetings, held biweekly during the academic year, is satisfying. The Annual Meeting, too, has become established as an important event for technical people of the textile and allied industries. In addition to these relatively organized efforts, TRI has maintained its policy of readiness to discuss textile research with anyone who desires to visit us, regardless of affiliation. Thus, within the limits of our budget, it appears that we are accomplishing our objective of furthering communication in the field.

It appears from the discussion thus far that TRI research, educational, and dissemination operations are going well. Shifting our attention from

the operational aspects to corporate policy and support, it is evident that the Institute's Board of Trustees has also functioned with great effectiveness. Although the full Board meets only four times annually, an amazing amount of business is done, and this was particularly true in 1961. As in the past, the Executive Committee, under the chairmanship of G. T. Gardner, has played an important role in analyzing policy and support problems prior to their consideration by the full Board. Similarly, the Finance Committee, chaired by Levon M. Yacubian, has worked closely with our Secretary-Treasurer, P. C. Alford, Jr., in a very constructive manner. Other committees of the Board have carried out their assignments with enthusiasm and originality in the recommendations resulting from their deliberations.

The Institute experienced a setback in 1961 when the Supreme Court of New Jersey ruled that TRI does not qualify for local tax exemption under the statute definitions of a college. This was not a financially serious matter, for TRI had been paying local taxes, under protest, and these taxes are not excessive. An important principle is involved in this decision, however, for TRI reincorporated in New Jersey in 1951 as an institution of higher learning and met all the requirements of the New Jersey Board of Education. It must be noted further that on the basis of the High Court's adverse decision the New Jersey Division of Taxation reversed its previous position that TRI was exempt from the State Corporation Business Tax. The Institute, through its attorney, has taken exception to this latter ruling, but this matter is currently pending.

In addition to relieving the Institute from such vexing tax matters, a number of other advantages would result from full legal recognition of TRI as an educational institution. It is possible that certain changes in the Institute's Certificate of Incorporation and Bylaws would accomplish this purpose without requiring major changes in our mode of operation. Undoubtedly, this will be an important matter for the Board to take up in 1962.

Considering the rather uncertain state of business and industry in the past year, TRI would seem to deserve commendation for operating "in the black." As will be noted later in this report, there was a modest excess of income over expense of about $6,000. Referring to the accompanying table, it is seen that total income was down by about $9,000, as compared to that of 1960. Paring expenses to yield a black figure was not easy, of course, but this was done without reduction in staff. Thus, TRI has its research

group intact and with continued support by the Membership and the application of sound methods to increase TRI income by Trustees and staff, an upward trend in income and activity can be resumed.

TRI INCOME—1961 vs. 1958, 1959, and 1960

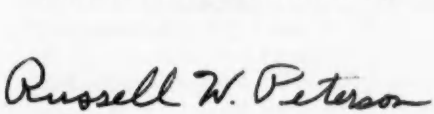
	1958	1959	1960	1961
GENERAL INCOME				
Membership dues	$106,836	$110,929	$122,496	**$112,038**
*Less credit to Pub. Dept.	(11,102)	(13,702)	(14,419)	**(13,426)**
Fellowship Grants	12,750	16,367	15,833	**23,750**
Miscellaneous	3,426	2,600	2,572	**4,101**
Publications Dept.	50,930	60,822	65,988	**67,813**
Total General Income	$162,840	$177,016	$192,470	**$194,276**
PROJECT INCOME				
Group Projects	$ 90,652	$142,462	$149,953	**$164,282**
Government Projects	60,423	75,954	67,469	**66,707**
Individually Sponsored Projects	58,984	44,353	49,743	**25,699**
Total Project Income	$210,059	$262,769	$267,165	**$256,688**
Total Income	$372,899	$439,785	$459,635	**$450,964**

*This is a credit to the Publications Department for subscriptions to *Textile Research Journal* furnished to TRI members.

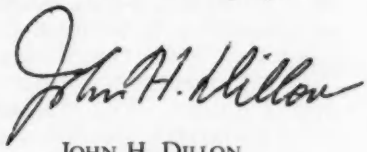
It has been pointed out on several occasions that the bulk of TRI's general funds, derived from Member dues and fellowship grants, is now expended in maintaining the program of graduate education; most of our staff research is supported by project income. This situation was taken under consideration by the Committee on Fellowships and Grants, under the leadership of Dr. Herschel H. Cudd. They concluded that TRI is in an excellent position to contribute to the future success of the industry through long-range basic research and that this could be done by expanding the research program to include additional postdoctoral fellows of outstanding ability. It was estimated that five such postdoctoral fellows, with laboratory assistants, could be accommodated in our present laboratories. Figuring the cost of this program at $125,000 annually, they made exploratory inquiries among a few member organizations and encountered very encouraging reactions. In fact, as this report goes to press, about one half of the $125,000

annual sum has been pledged. The program will be publicly announced in 1962 and there is every reason for optimism that the goal will be achieved.

Practically no industrial firm today questions the importance of research and development to its future. Nearly every company leader will agree that the prosperity and probably even the existence of his company in the increasingly competitive years ahead will depend upon the development of a procession of profitable new products. The successful developments of today are built on the basic research of yesterday. We of the textile industry are doing only a small amount of basic research and this will handicap us in the years ahead. Somehow we must find ways to do more. There is also a great shortage of technical men today, especially in our industry. We do not compete effectively for technical manpower, and we must have good technical men if we are to come forth with new developments. TRI is trying to make a modest contribution toward these goals through expansion of its basic research effort, and it is hoped that other organizations of the textile and allied industries will join with it in this worthwhile program.



RUSSELL W. PETERSON
Chairman of the Board of Trustees



JOHN H. DILLON
President

OFFICERS

RUSSELL W. PETERSON, *Chairman of the Board*
G. T. GARDNER, *Vice Chairman of the Board and Chairman of the Executive Committee*
LEVON M. YACUBIAN, *Chairman of Finance Committee*
JOHN H. DILLON, *President*
PAUL C. ALFORD, JR., *Secretary-Treasurer*

BOARD OF TRUSTEES

ROBERT T. ARMSTRONG, Vice President & Technical Director, Celanese Corporation of America
FREDERICK L. BISSINGER, Group Vice President, Midland-Ross Corporation
DAVID W. CHANEY, Executive Director, Chemstrand Research Center, Inc.
W. E. CLARK, Vice President & General Manager, Textile Division, United States Rubber Company
SYDNEY M. CONE, JR., Vice President, Cone Mills Corporation
HERSCHEL H. CUDD, President, AviSun Corporation
J. LINDSAY DEXTER, Assistant Treasurer, Pepperell Manufacturing Company
G. T. GARDNER, Executive Vice President, Riegel Textile Corporation
J. B. GOLDBERG, Technical Consultant to the Textile and Allied Industries
NORMAN S. GRACE, General Manager, Dunlop Research Centre
WALTER J. HAMBURGER, Director and Treasurer, Fabric Research Laboratories, Inc.
JOHN J. HANLON, Technical Director, Mohasco Industries, Inc.
CARLYLE HARMON, Vice President, Research, Chicopee Manufacturing Corporation
BERTRAND W. HAYWARD, President, Philadelphia College of Textiles and Science
HAROLD F. HEDBERG, Vice President—Research, Albany Felt Company
GEORGE H. HOTTE, Executive Vice President, Texplant Corporation
ROBERT M. JONES, Vice President and Director of Research, Saco-Lowell Research and Development Center
CLIFTON H. KARNES, Coordinator, Research and Development Center, Burlington Industries, Inc.
KENNETH H. KLIPSTEIN, President, American Cyanamid Company
L. O. KOONS, President, Scholler Brothers, Inc.
RICHARD T. KROPF, President, Belding Heminway Company, Inc.
EDWARD W. LAWRENCE, Director of Research, Cranston Print Works Company
GERALD LAXER, Director of Science and Technology, The Wool Bureau, Inc.
W. W. MCLEOD, Vice President and Director of Research, Coats & Clark Inc.
J. G. MCNALLY, Vice President and Director of Research, Tennessee Eastman Company (Div. of Eastman Kodak Company)
CHARLES H. MASLAND 3RD, Vice President for Engineering, C. H. Masland & Sons
RUSSELL B. NEWTON, Chairman of the Board, Deering Milliken Research Corporation
CHARLES L. PAINE, President, Courtaulds (Alabama) Inc.

RUSSELL W. PETERSON, Technical Director, New Products Division, Textile Fibers Department, E. I. du Pont de Nemours & Co., Inc.
WALTER REGNERY, Vice President, Joanna Cotton Mills Company
LEONARD SMITH, Director of Utilization Research, National Cotton Council of America
PAUL B. STAM, Vice President, Research, J. P. Stevens & Co., Inc.
LEVON M. YACUBIAN, Vice President and General Manager, The Barre Wool Combing Company, Ltd.

BOARD COMMITTEES

Executive
G. T. GARDNER, *Chairman*
W. E. CLARK
KENNETH H. KLIPSTEIN
RICHARD T. KROPF
W. W. MCLEOD
RUSSELL W. PETERSON
LEVON M. YACUBIAN

Fellowships and Grants
HERSCHEL H. CUDD, *Chairman*
ROBERT T. ARMSTRONG
DAVID W. CHANEY
GEORGE H. HOTTE
KENNETH H. KLIPSTEIN
J. G. MCNALLY
RUSSELL B. NEWTON
CHARLES L. PAINE
RUSSELL W. PETERSON
PAUL B. STAM

Finance
LEVON M. YACUBIAN, *Chairman*
PAUL C. ALFORD, JR.
JOHN H. DILLON
G. T. GARDNER
RUSSELL W. PETERSON

Meetings and Awards
GEORGE H. HOTTE, *Chairman*
J. B. GOLDBERG
W. J. HAMBURGER
LEONARD SMITH
PAUL B. STAM

Membership
RICHARD T. KROPF, *Chairman*
FREDERICK L. BISSINGER
SYDNEY M. CONE, JR.
J. LINDSAY DEXTER
NORMAN S. GRACE
CARLYLE HARMON
HAROLD F. HEDBERG
L. O. KOONS
WALTER REGNERY

Nominations
For Trustees (1962)
ROBERT M. JONES, *Chairman*
A. GRIFFIN ASHCROFT
GEORGE S. BUCK, JR.
C. H. MASLAND 3RD
DONALD H. POWERS

For Officers (1962)
GERALD LAXER, *Chairman*
BERTRAND W. HAYWARD
EDWARD W. LAWRENCE

Officers and Trustees at Board of Trustees meeting on March 15, 1961. From left to right, first row, Messrs. Lawrence, Hotte, Dillon, Clark, Peterson, Allen, Yacubian, Armstrong; second row, Chaney, Smith, Cudd, Stam, Dexter, Hayward, Kropf, McNally, Grace, Alford; third row, Klipstein, Hedberg, Masland, Koons, Harmon, McLeod, Hamburger, Goldberg.

G. T. GARDNER
Vice Chairman of the Board
and Chairman of the Executive Committee

P. C. ALFORD, JR.
Secretary-Treasurer

ADVISORY COMMITTEES

RESEARCH

EDWARD W. LAWRENCE, *Chairman,* Director of Research, Cranston Print Works Company

RICHARD O. STEELE, *Vice Chairman,* Research Laboratories, Rohm & Haas Company

NORMAN C. ARMITAGE, Vice President, Deering Milliken Research Corporation

WILLIAM S. BARNARD, Research Department, Chicopee Manufacturing Corporation

RALPH H. BEAUMONT, JR., Director of Chemical Research, Huyck Felt Company

C. W. BENDIGO, Director of International Services, Burlington International

R. H. BRAUNLICH, Manager, Research & Development, Fibers Division, American Viscose Corporation

WALLACE R. BRODE

DAVID W. CHANEY, Executive Director, Chemstrand Research Center, Inc.

THEODORE F. COOKE, Director, Chemical Research Department, Organic Chemicals Division, Bound Brook Laboratories, American Cyanamid Company

CLYDE W. DAVIS, Research Department, The Dow Chemical Company

J. L. DELANEY, General Superintendent, Joanna Cotton Mills

NICHOLAS DRISCH, Managing Director of Research Department, Comptoir des Textiles Artificiels

A. MASON DUPRÉ, JR., Assistant to Administrator, Agricultural Research Service, U. S. Department of Agriculture

GEORGE R. ECKHARDT, Director of Research, Research Laboratories, Coats & Clark Inc.

T. WALLER GEORGE, Celanese Corporation of America

L. AUBREY GOODSON, JR., Vice President and Director of Research, Dan River Mills, Incorporated

CARL GORDON, Chief Chemist, Albany Felt Company

NORMAN S. GRACE, General Manager, Dunlop Research Centre

M. EARL HEARD, Vice President, Research, West Point Manufacturing Company

WILLIS A. HEISEY, Chief Chemist, Geo. W. Bollman & Co., Inc.

GILMAN S. HOOPER, Director, Research and Development, Fiber Development Department, Hercules Powder Company, Inc.

DONALD F. HORNIG, Chairman, Department of Chemistry, Princeton University

CLIFTON H. KARNES, Coordinator, Research & Development Center, Burlington Industries, Inc.

HANS O. KAUFFMAN, Director, Inorganic Research and Development Department, FMC Corporation

GERALD LAXER, Director of Science and Technology, The Wool Bureau, Inc.

HERMAN MARK, Director, Polymer Research Institute, Polytechnic Institute of Brooklyn

WILLIAM H. POISSON, Manager, Planning and Evaluation, Fiber Marketing Department, National Aniline Division, Allied Chemical Company

DONALD H. POWERS, Assistant Director, Fabric Research Laboratories, Inc.

E. W. RUGELEY, Senior Technical Advisor & Coordinator, Textile Fibers Department, Union Carbide Chemicals Company

HERBERT F. SCHIEFER, Chief, Textiles Section, Organic & Fibrous Materials Division, National Bureau of Standards

STUART H. SHERMAN, Development Manager, Textile Division, United States Rubber Company

ARTHUR L. SMITH, Technical Director, Chatham Manufacturing Company

RICHARD D. SMITH, Manager, Synthetic Fiber Development, The B. F. Goodrich Chemical Company

ARNOLD M. SOOKNE, Associate Director, Harris Research Laboratories, Inc.

PAUL B. STAM, Vice President, Research, J. P. Stevens & Co., Inc.

REINER G. STOLL, Assistant Director of Marketing, Plans and Programs, Celanese Corporation of America

JOHN M. SWANSON, Laboratory Director, Textile Research Laboratory, Textile Fibers Department, E. I. du Pont de Nemours & Co., Inc.

HUGH S. TAYLOR, President, Woodrow Wilson National Fellowship Foundation

N. B. TUCKER, Director, Research Division, Miami Valley Laboratories, The Procter & Gamble Company

HELMUT WAKEHAM, Vice President, Philip Morris Incorporated

J. W. WEAVER, Manager, Central Laboratory, Cone Mills Corporation

JOHN WHARTON, Director of Research, Courtaulds (Alabama) Inc.

ERNST A. WOLFF, Technical Manager, Chemical Specialties Division, CIBA Company, Inc.

EDUCATION

BERTRAND W. HAYWARD, *Chairman*
President, Philadelphia College of Textiles and Science

R. M. DRAKE, JR.
Chairman, Department of Mechanical Engineering, Princeton University

CARLYLE HARMON
Vice President, Research, Chicopee Manufacturing Corporation

DONALD F. HORNIG
Chairman, Department of Chemistry, Princeton University

HERMAN MARK
Director, Polymer Research Institute, Polytechnic Institute of Brooklyn
LEONARD SMITH
Director of Utilization Research, National Cotton Council of America
HUGH S. TAYLOR
President, Woodrow Wilson National Fellowship Foundation
R. H. WILHELM
Chairman of Department of Chemical Engineering, Princeton University

PUBLICATIONS

WALTER J. HAMBURGER, *Chairman*
Director and Treasurer, Fabric Research Laboratories, Inc.
GERALD LAXER
Director of Science and Technology, The Wool Bureau, Inc.
C. H. MASLAND 3RD
Vice President for Engineering, C. H. Masland & Sons
ELMER HUTCHISSON
Director, American Institute of Physics
W. W. MCLEOD
Vice President and Director of Research, Coats & Clark Inc.

PATENTS

GEORGE H. FREMON, *Chairman*
Patent Co-ordinator, Union Carbide Chemicals Company
NORMAN C. ARMITAGE
Vice President & Technical Director, Celanese Corporation of America
JOHN J. HANLON
Technical Director, Mohasco Industries, Inc.
ROBERT M. JONES
Vice President and Director of Research
Saco-Lowell Research and Development Center
ALBERT SPERRY
TRI Patent Attorney

W. James Lyons
Associate Research Director

Ludwig Rebenfeld
Associate Research Director
and Education Program Director

Robert F. Schwenker, Jr.
Associate Research Director

RESEARCH

Structure and Chemistry of Cellulose	15
Studies of Keratin Fibers	17
Synthetic Fibrous Polymers	21
Thermal Behavior of Textile Materials	23
Physics of Fibers	26
Properties of Fiber Assemblies	30
Chemical Treatments of Cotton	33

This account of TRI research findings in 1961 has been prepared without regard to sponsorship, personnel assignments, and project limitations. An attempt is made to give for each research topic the general reason for doing the work, the methods employed, and a few significant results. Information on who did the research and how it was supported can be found in the Appendix. The same categories under which the 1960 TRI research program was described have been used: *Structure and Chemistry of Cellulose, Studies of Keratin Fibers, Synthetic Fibrous Polymers, Thermal Behavior of Textile Materials, Physics of Fibers, Properties of Fiber Assemblies,* and *Chemical Treatments of Cotton.*

Structure and Chemistry of Cellulose

In recent years research on the chemical modification of cellulose has resulted in expanded uses for both natural and man-made cellulosic fibers. In order to approach the full potential of this most abundant and important of fiber materials a viable research program in cellulose chemistry and structure is being maintained at TRI. New techniques are being employed to probe the many enigmatic aspects of cellulose structure. Chemical modification is receiving increased emphasis in a search for improved cellulose reactions and new cellulose derivatives.

Sodium Cellulosate Reactivity: In the first phase of a study on cellulose reactivity it was shown that sodio derivatives of cellulose, sodium cellulosates, could be conveniently prepared via an exchange reaction between cellulose and a sodium alkoxide. The efficacy of sodium cellulosate as an intermediate in the preparation of various cellulose derivatives has now been investigated. Sodium

cellulosates of DS 0.5 to 1.2, with respect to sodium substitution, were obtained by the reaction of sodium butoxide with cotton cellulose, and the reactivity of the sodio compounds was studied.

Ester and ether derivatives were prepared by the condensation of selected reagents with the sodio intermediates of cellulose and alkali cellulose. The data obtained indicated a high degree of conversion from the sodium cellulosates to certain ether and ester derivatives. The products were characterized by thermoanalytical techniques. In general, the reactions proceeded more rapidly with sodium cellulosates than with alkali cellulose substrates. Significant differences in properties of similar derivatives from the two substrates were observed in many instances.

Study of End-Groups in Methylated Cellulose: Since the discovery by Denham and Woodhouse in 1914 of a trace of tetramethylglucose in the hydrolyzate of a methylated cellulose, the presence or absence of such an end-group in cellulose has become one of the outstanding questions bearing on the correct structural formula of cellulose. In view of numerous conflicting reports in the literature an independent study of this unresolved question has now been initiated. It is hoped that the sensitive, new analytical techniques now available, notably gas–liquid chromatography, will permit the detection and separation of 2,3,6-tri-O-methyl- and 2,3,4,6-tetra-O-methyl-D-glucose on a qualitative as well as a quantitative basis. Experiments are being carried out involving the acid hydrolysis of both methylated cellulose and cellulose reduced with sodium borohydride, followed by analysis of the resultant hydrolyzates for the presence of the previously indicated methyl glucoses. It is the objective of this work to provide an unequivocal answer to the basic question of how the cellulose chain ends.

Location of Cross-Links and Other Substituents in Cellulose Derivatives: Although the chemical modification of cellulose by the introduction of cross-links and other substituents has been extensively studied, very little is known about the exact location of the substituents on the anhydroglucose units in the partially reacted cellulose molecule. Exhaustive methylation of such products with subsequent acid hydrolysis down to the monomeric state should yield D-glucose and various, partly methylated glucose derivatives. The identification and quantitative separation of the components in such hydrolyzates is being attempted by gas–liquid chromatography and other modern methods. The study of the original, unhydrolyzed cellulose products via periodic acid oxidation is also being carried out. This research is a continuation of similar work, involving cellulose-formaldehyde derivatives, which was published in 1952.

Dr. Weigmann and Mrs. Dansizer.

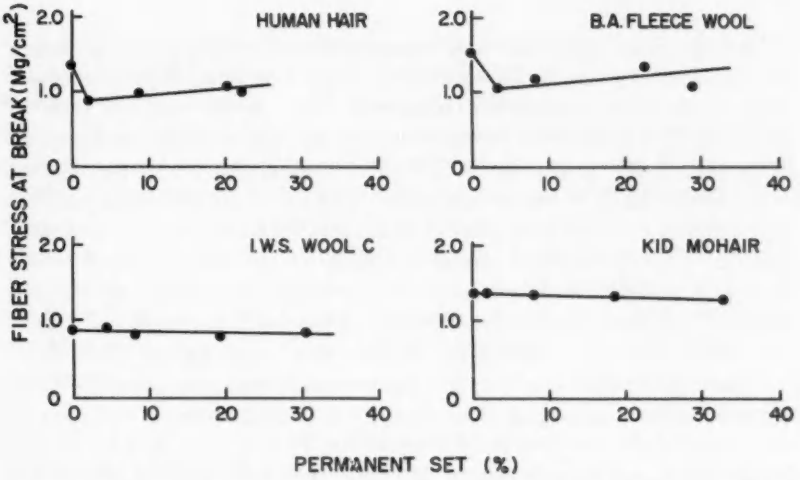
Studies of Keratin Fibers

The keratin fibers constitute one of the most important classes of natural fibers used in the textile industry and provide a variety of intriguing problems requiring scientific investigations of extreme complexity and challenge. While a great deal is now known about the chemical and physical structure and about the mechanical properties of keratin fibers, the ever increasing industrial use of chemical treatments and modifications makes necessary an even more complete and precise knowledge of fiber structure and properties. Treatments designed to impart minimum-care characteristics to wool fabrics are but one example of commercially significant developments which were brought about as a result of long-range and painstaking fundamental research in the chemistry and physics of keratin fibers. During 1961 research at TRI relating to keratin fibers centered around three programs which are designed to provide the scientific background for future industrial developments. One of these involves the use of the highly specialized optical rotatory dispersion technique, and should give us a better understanding of the configuration of protein molecules in various chemical environments and under varying conditions of temperature. The other programs, on the permanent set and supercontraction of keratin fibers, are providing information about the effects of certain chemical reagents on the characteristics of the macroscopic fiber. Knowledge about both these levels of organization, namely the protein molecule and the keratin fiber, is necessary in order that the best utilization be made of the inherent qualities of keratin fibers.

Optical Rotation Studies: It has been shown in the case of synthetic polypeptides and globular proteins that by measuring optical rotations of solutions of these materials, using incident light of different wavelengths, it is possible to make certain deductions regarding the configuration of the protein molecule. The properties of wool in solution have never been studied, since the fiber is insoluble in nondegradating solvents. It is possible, however, to isolate rather large soluble polypeptides from wool by suitable extraction techniques and to establish the spatial configuration of these fractions by the use of optical rotatory dispersion. Many proteins exhibit patterns of folding in solution which vary as a function of solvent, pH, and temperature. The nature of the folding determines to a great extent the interesting properties possessed by each protein, and a study of the transitions possible between folded and unfolded configurations under various conditions can lead to deductions as to the nature of the forces necessary for maintaining the structural integrity of the protein.

The behavior of keratose, which is an oxidation product of wool, is for the most part consistent with the behavior of ordinary soluble proteins. The molecules of this wool fraction are partially folded in water, and it is believed that much of this folding is due to the development of a helical configuration of the polypeptide, which is stabilized by intramolecular hydrogen bonds along the amino acid backbone. In solvents, such as concentrated urea solutions, that can compete successfully with the protein for the hydrogen bonds, the unfolded or random configuration is favored. In solvents, such as ethylene glycol, that do not compete for hydrogen bonds, a greater extent of folding occurs than in water. In dimethylformamide, a solvent usually associated with the folded helical structure, the experimental results suggest the formation of an unexpected intermolecularly hydrogen bonded structure. An increase in the temperature tends to break down the hydrogen bonds which are necessary for the stability of the folded structure and the unfolded random configuration is favored. In environments of high pH the protein molecule assumes a negative potential, which also inhibits the stability of the folded configuration.

Permanent Set: The increase in length of a keratin fiber when it is subjected to various chemical treatments while it is held in a strained condition is referred to as set. Such an increase in fiber length, whether it be permanent or temporary, is the result of rearrangements at the molecular level involving hydrogen bonds, salt linkages, cystine bonds, and functionally significant side groups of the keratin protein. In view of these fundamental changes in the fiber structure, experiments were conducted to establish the effects of permanent setting on the mechanical properties of four different keratin fiber types, which were chosen on the basis of their varied ortho-para cortical structure. The set was imparted by holding single fibers at various strain levels in boiling water and subsequently



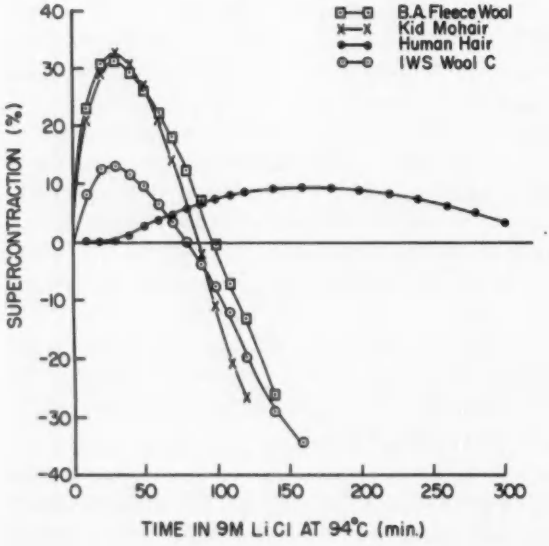
The effects of imparting permanent set to single fibers, of four keratin fiber types, on stress at break.

allowing them to relax in boiling water. The mechanical properties of the set fibers were compared with both untreated fibers and with fibers which were subjected to the boiling water treatment under no strain. Human hair, a crimped Merino wool, a coarse, low-crimp wool, and a kid mohair were used for these studies. It was observed that the changes in mechanical properties resulting from the set were significantly different, in many instances, among the four fiber types. Attempts have been made to relate these differences to the ortho-para cortical structure, but it has not been possible so far to reach definitive conclusions.

The effects of permanent setting on fiber mechanical properties were compared with the effects of a setting treatment which is designed to impart a partly permanent and partly temporary set. Such a set may be brought about by variations in the conditions used during the relaxation step. Significant differences in the mechanical properties were found between fibers containing permanent set only and those having both a permanent and a temporary set, despite the fact that the over-all increase in length was identical. These experiments indicate the importance of the relaxation process during a setting treatment and suggest that during the relaxation process molecular rearrangements are taking place which are of importance in terms of fiber mechanical properties.

Supercontraction: When a keratin fiber is subjected to the action of various chemical reagents, the fiber will undergo a decrease in length which is referred to as supercontraction. The extent of this dimensional change, which is accompanied by a corresponding increase in cross-sectional area, is highly dependent upon the restraining force which is exerted along the fiber axis. Chemical reagents

which bring about supercontraction in keratin fibers are those capable of causing disulfide bond scission, hydrogen bond breakdown, or both. Supercontraction, therefore, results in alterations to fundamental structure and must be dependent upon both the chemical and physical structure of the fiber itself. A study of the kinetics of supercontraction under carefully controlled conditions should allow a better understanding of the mechanism involved and of the role which the fiber structure plays in this scientifically intriguing and industrially significant process. Particular attention has been given to a study of supercontraction of keratin fibers with different cortical structures in an attempt to determine the rate and extent of supercontraction of the ortho and para cortex. The supercontraction in 9 *M* LiCl at 94°C of the same types of fibers which were used in the study of permanent set revealed that the rates and extents of supercontraction were significantly different among the four fiber types. Careful attention was given to maintaining the initial fiber stress constant for the four fiber types by varying the restraining load on each fiber to correspond with the differences in cross-sectional area. In these controlled supercontraction experiments it was observed that the kid mohair and the B.A. fleece wool fibers (coarse, low-crimp) supercontracted to the greatest extent, while human hair supercontracted least. The highly crimped Merino wool, designated as I.W.S. Wool "C," exhibited inter-



Supercontraction behavior of single fibers from four keratin fiber types in 9 *M* LiCl at 94°C. Each fiber is maintained under stress of 11.0 kg./cm.^{2} during supercontraction process.

mediate behavior. It was of interest that human hair, which is an all-para-cortex fiber, did not undergo supercontraction during the first 30 minutes, by which time the other fibers had already attained their maximum supercontraction. It is felt that these differences in supercontraction are to be associated primarily with differences in the ortho-para cortical structure, which suggests further that basic chemical differences exist between the ortho and the para cortex of keratin fibers. Experiments are also underway to follow the supercontraction of these fibers microscopically in order that additional features of this process may be discerned. For example, it was observed that during the supercontraction of a highly crimped bilateral wool fiber, a crimp inversion takes place which may again be associated with differences in the rates of supercontraction of the ortho and para cortex.

Synthetic Fibrous Polymers

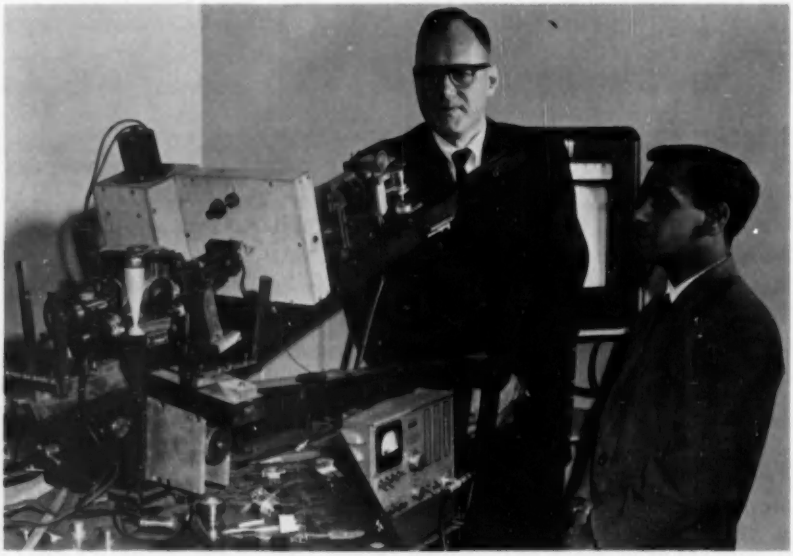
It has become evident that the truly synthetic fibers now occupy a permanent position in the more conventional portions of the textile field. Furthermore, they exhibit potentials for applications never envisioned for the natural or the older man-made fibers. To facilitate expansion of their uses into these new unorthodox fields, it is logical for TRI to pioneer in developing a better understanding of fiber behavior in terms of the microstructure upon which it is based. This indeed formed an important part of the TRI research program in 1961. In addition, studies of the kinetics of dyeing in terms of microstructure were carried out with the dual possibility of suggesting better dyeing approaches and, using dyeing as a tool, learning more about fiber microstructure itself.

Fiber Behavior as a Function of Molecular Parameters: The theory of amorphous polymers, particularly rubber-like polymers with randomly coiled chains exhibiting "entropy elasticity," has been developed to a high degree within the past two decades. The more complicated case of the oriented, crystalline polymer has proved intractable. Thus the development of synthetic fibers has been based largely upon qualitative concepts and empirical information. Recent work at TRI, however, has resulted in a new approach to the quantitative understanding of the physical behavior of oriented, crystalline polymers (of which textile fibers form an important class), in terms of the crystallinity, size of crystals, average length of molecules, and state of orientation.

This advance has been achieved by employing the concept of the Markoff chain. The analysis involves rather specialized matrix methods, which have led to the development of probability functions that yield quantitative relationships between various measurable physical quantities and the molecular parameters—

crystallinity, crystal size, molecular segment length, and state of orientation. In particular, the thermal shrinkage of a fiber has been related to degree of crystallinity and crystal size.

The potential usefulness of such relationships in the development of synthetic fibers is, of course, quite clear. Conceivably, such knowledge would also be useful in modifying existing natural and man-made fibers. But, before these theories can be put to use, they must be subjected to exhaustive experimental verification. A TRI team is already carrying out critical experiments involving x-ray diffraction measurements of crystallinity and crystal size, density determinations, and modulus studies, with temperature as an important independent variable. Thus far, the theory has stood up well under experimental scrutiny.



X-ray diffraction equipment—Professor Tobolsky and Dr. Gupta.

Dyeing Kinetics as Related to Microstructure: It is recognized that microstructural characteristics of fibers such as crystallinity and orientation affect the rate of dyeing. Publications in this field are not very extensive, however, and the possibility of shedding light on the fiber microstructure itself justified a TRI research assignment made late in 1960. The work thus far has involved dyeing rate and equilibrum experiments, using the acid dye, Orange II, with samples of nylon 6 and nylon 66 filaments prepared from the same batches of polymer but with several different draw ratios. Results of preliminary runs indicate a strong negative dependence of dyeing rate upon draw ratio. Under the conditions of

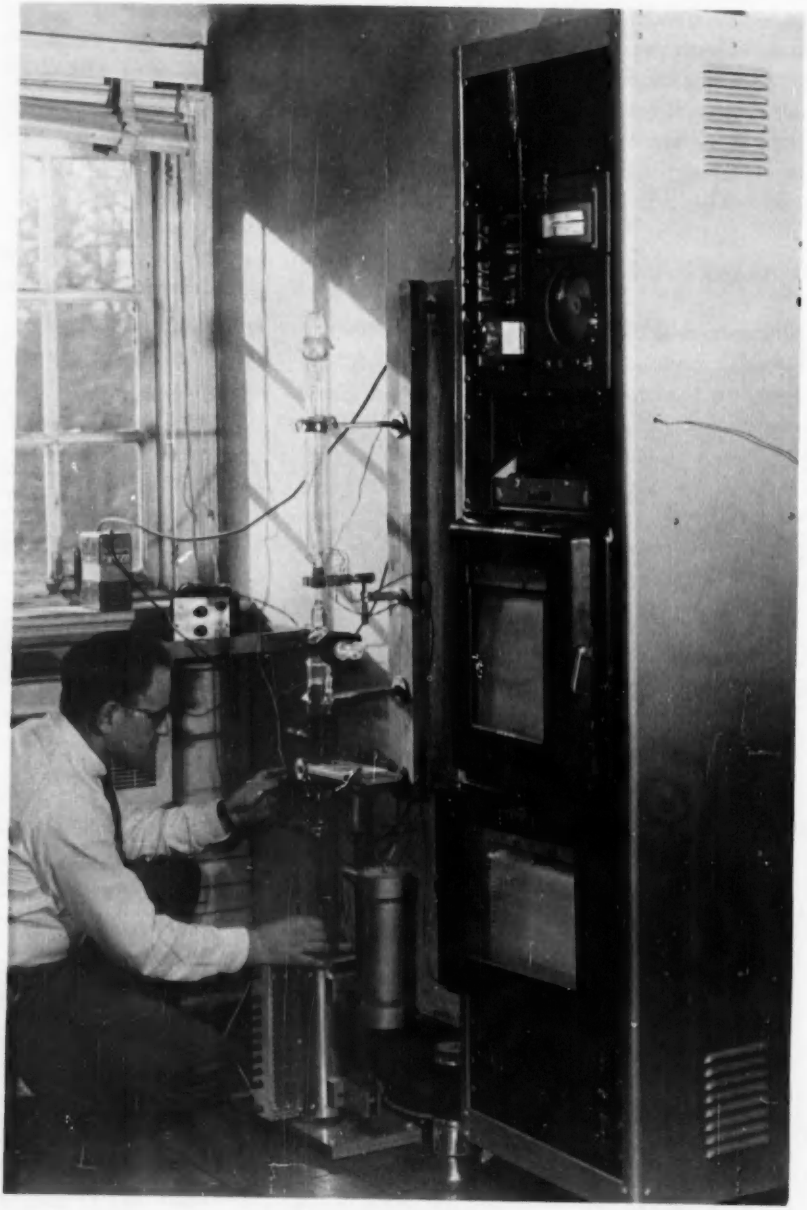
these experiments, the rate-controlling process should be the diffusion of the dye anion within the fiber. Thus, diffusion coefficients were calculated at various times during the dyeings, using Hill's solution of Fick's second law in cylindrical coordinates. It was found that the diffusion constant decreased considerably with time in a given dyeing experiment. The work is being continued with special emphasis on the factors, pH, temperature, dye concentration, salt concentration, and type of buffer.

Thermal Behavior of Textile Materials

This research is concerned, in the broadest sense, with the development of fundamental knowledge as to the responses of textile materials to thermal stress. Recently, emphasis has been placed on the application of dynamic methods of thermal analysis in assaying the thermal characteristics of textile materials. These methods are (1) differential thermal analysis (DTA), (2) thermogravimetric analysis (TGA), and (3) gas chromatography. The results obtained indicate these methods to be tools of unusual potential for characterization and for studies of reaction and degradation mechanisms. Using these and other techniques, studies have been carried out on the chemical treatment of cotton for flame and heat resistance as well as on the thermal stability of synthetic textile materials.

Apparatus and Techniques: An apparatus for thermogravimetric analysis has been constructed based on a design used commercially. The balance component is a spring deflection-type involving suspension of the sample holder from a pair of matched, helical, metal springs. As changes in the weight of the sample occur, extension or contraction of the springs, resulting in the vertical displacement of the sample holder linkage, is measured by means of a linear variable differential transformer. Weight changes are thus automatically recorded to give a plot of weight loss versus temperature which results in a stepped curve. The spring assembly is suspended from the top of a glass column which also encloses the sample holder. The lower end of the column, containing the sample holder, fits into the core of an electric furnace. The glass enclosure permits operation in vacuum or at ambient pressures in a controlled atmosphere. Heating rate is controlled by an automatic temperature programmer. Thermocouples are positioned at the base of the sample holder for temperature measurement. The present range of operation is from 25° to 1000° C at heating rates of 1° to 15° C per minute. Samples in the range of 25 to 200 milligrams can be conveniently handled.

Techniques have been developed for the decomposition of textile materials directly in the gas stream of the gas chromatograph. This permits degradation to take place in less than ten seconds with products swept directly onto the column,



Thermogravimetric analysis unit—Robert K. Zuccarello.

thus materially reducing the danger of losing products of high volatility and of secondary reactions or further degradation of the products.

Pyrolytic Degradation Studies: Studies have been carried out on the pyrolytic decomposition of cellulose and nylon 66. The products arising from pyrolysis have been determined by gas–liquid chromatography using a temperature programmed gas chromatograph with a hot wire detector. Samples of cotton and nylon have been pyrolyzed in air and in nitrogen in an apparatus specially made for the purpose. The decomposition products were collected in cold traps at temperatures from 0 to -78° C. Other samples of these materials were pyrolyzed within the gas chromatograph block in the helium stream by means of an electrically heated wire loop. A total of twenty major products has been identified for cellulose including seven products not previously reported. It was also found that the major products were the same irrespective of the atmosphere employed.

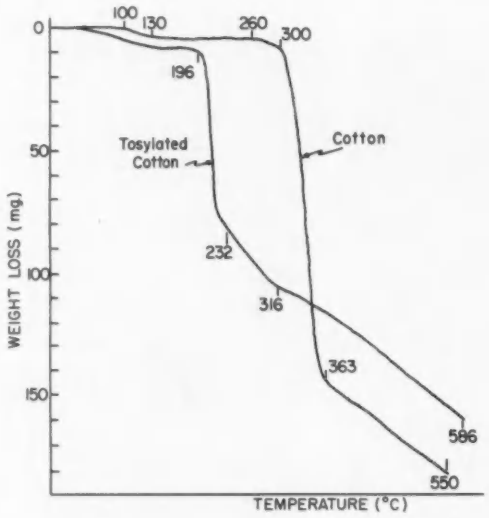
Similar pyrolysis experiments have been performed on nylon 66 and the products analyzed by gas chromatography. A minimum of twenty-five products was found to be present. Ammonia, water, hexylamine, cyclopentanone and hexamethylene-diamine were identified as major products.

Thermal Characteristics of Textile Materials: The effects of elastomers as coatings on cotton and nylon substrates have been studied by thermogravimetric analysis (TGA). Fabric samples were double-coated with Neoprene W*, butyl rubber, and Hypalon-20*. The thermal stability of each system was evaluated, with thermal stability defined by the initial decomposition temperature and the rate of decomposition. The results indicated the cotton–butyl system to have the greatest thermal stability, followed closely by the nylon–butyl combination. The other coated materials exhibited thermal stabilities lower than those of the base substrates. Neoprene W was the least stable material, with rapid volatilization occurring at 140° C.

Further work on reducing the heat transmission of textile structures, for the special case of a flame impinging on the structure, was carried out. Attempts to reduce heat transmission to tolerable levels (about 25% transmission) by chemically treating or coating even fairly heavy fabrics (up to 13 oz./yd.^{2}) were unsuccessful. It was found that two-ply fabrics of cotton bonded together with a flame-resistant Neoprene cement were required to obtain reductions of the order of 75% to 80%. In these plied or combined fabrics a fairly heavy cotton, resin-treated for flame and glow resistance, was needed for the side exposed to the heat or flame contact. With such structures the temperature across the fabric boundary could be reduced from 800°C to 150°C for periods of several seconds.

The behavior of various textile substrates has been studied by TGA to obtain

**Du Pont trademark*



TGA curves in air for cotton and tosyl cellulose (200 mg. sample size).

information on thermal stability and data for correlation with DTA results on the same materials. The TGA curves of cotton cellulose showed slow decomposition starting at 280°C, with a very fast reaction taking over at 325°C. Kinetic data on the depolymerization of cellulose were obtained from the TGA curves. Tosylated cotton (DS 0.3) had a decomposition temperature of 195°C indicating a substantial reduction in thermal stability over that found for unmodified cellulose. Nylon was found to exhibit two markedly different decomposition temperatures in air and nitrogen. In air the sample began to decompose at 290°C but in nitrogen no decomposition occurred until a temperature of 400°C was reached. The kinetics of nylon depolymerization were also studied using the TGA data. In all cases good correlation was observed between DTA and TGA results.

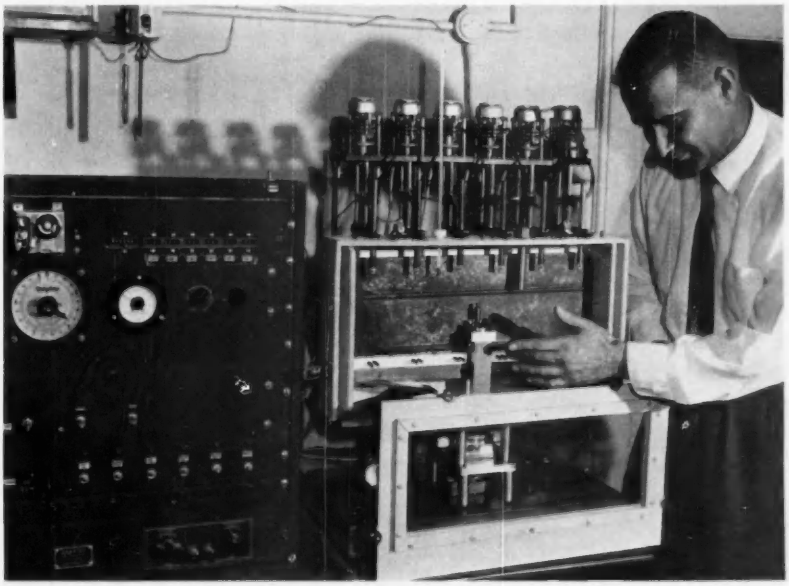
Physics of Fibers

Two research studies launched in earlier years, both involving extensive experimental work, were continued through 1961. These relate to fatigue in textile fibers and to fiber surface properties. Another study, of more modest scope than these projects, got underway during the year. This one, an analysis of the distribution of flaws in a monofilament sample, is statistical with regard to its initial objective; however, it has involved a large number of individual fiber breaking tests made by conventional techniques. The physical properties of fibers are, of course, of importance in many other projects, but largely as tools for assessing other aspects of an experiment.

Fatigue in Textile Fibers: In the continued program on fatiguing in cyclic tension, an experimental acrylic sample was dynamically loaded under various conditions, short of rupture, and the residual breaking properties then measured. No significant differences in these properties relatable to differences in frequency (in a four-fold range) or in fatiguing time (in a five-fold range) were found. The properties of the fatigued fibers as a group, however, were found to be appreciably different from those of an unfatigued control. These results were confirmed in a second experiment conducted at another stroke.

The investigation of the effect of frequency and stroke on the fatigue life of the acrylic fiber in cyclic tension has been continued. The data thus far obtained at 2.0% and 2.5% stroke fall about where they would be expected on the life-time-vs.-frequency plot. Tenacity–extension curves obtained on fibers broken in fatigue revealed substantial differences in the behavior of fatigued and unfatigued samples. The average tenacity of fatigued samples was higher than the tenacity of the unfatigued control. This has been interpreted as an indication that fatigue could be considered, in this particular case, to be a combination of two processes: structural changes within the fiber, and rupture of the weakest link.

An electrically heated oven has been added to the tension fatigue machine, so that the influence of another important variable, temperature, on the fatigue behavior of fibers can be studied. Information in this area, it is expected, will



Tensional fatigue tester—Dr. Prevorsek.

throw significant light on the validity of certain theories about the molecular mechanism of fatigue failure.

Further experiments in the fatiguing of fibers in biaxial rotation have been conducted. Of special interest have been the results on nylon 66 monofils of various draw ratios, heat-set and non-heat-set. It was found, for instance, that the non-heat-set monofils of low draw ratios can evidently be biaxially fatigued up to many thousands of revolutions with only a moderate loss in residual breaking tenacity, and without reaching a point of sharp decline in this parameter. The more highly drawn, and the heat-set samples showed a sharp decline after about 3000 to 4000 revolutions, and when 7000 revolutions had been completed, residual breaking tenacities were in the order of those of the samples of low draw ratio.

The nature of the degradation that occurs in biaxially fatigued monofils before and after a relatively well-defined point on the time scale at which the residual breaking tenacity of the specimens starts to decline rather abruptly has been explored. X-ray diffraction diagrams of the fatigued regions of nylon 66 and nylon 6 monofils showed that substantial deorientation of crystalline regions took place during the initial phase of the fatiguing, where small losses in tenacity were observed. Negligible changes in orientation, however, appeared to occur during the period of substantial loss in strength. The inference from these observations is that the cause of the decline in strength lies in the formation and propagation of cracks and in the degradation of polymer chains.

Fiber Surface Studies: Apparatus for characterizing both the frictional behavior and the geometric roughness of fiber surfaces has been developed to the stage that preliminary chart recordings, as well as digital data, demonstrating the performance of the two systems on representative fiber specimens, have been obtained. Exploratory measurements with the initial equipment for surface-geometry analysis revealed the need for a sensing device (transducer) having better frequency response, and a more sensitive chart recorder. New units meeting these needs, as well as additional components in the intermediate electronic circuitry, have been put into service. The system now provides records interpretable in terms of the number of asperities in a given length of fiber surface, their relative positions along the surface, and a summation of their heights. It is believed that, with these parameters, it will be possible to characterize the surface of a fiber sample with respect to the degree of geometric roughness.

An improved feature of the arrangement is the use of a smoothly operating, hydraulically driven mechanism for moving the specimen fiber across the probe of either the frictional-force or the surface-geometry transducer. Use of this technique avoids the need for successively mounting and remounting a specimen for

these measurements and thus promises the possibility of obtaining both frictional and geometrical data on (to a large degree) the identical profile or aspect of the surface of the specimen. This may in turn, provide data of enhanced validity on which conclusions regarding the relationship between "stick-slip" frictional phenomena and the distribution of asperities on fiber surfaces can be based.

The chart recordings of frictional force along delustered and undelustered Dacron* fibers have shown gratifying similarities among specimens of the same sample, and substantial differences among different samples. The stick-slip phenomenom was indicated, and quantitatively, the tracings conformed in character to what would be expected from the two samples. The preliminary surface-geometry data, obtained on a number of animal fibers, have shown, under favorable testing conditions, good reproducibility in repeated scannings of the same specimen; though (not wholly unexpectedly) dissimilarities were found among specimens of the same fiber type.

Exploratory trials of the two systems, in the course of their development as outlined above showed them to have become highly sensitive to building and other mechanical vibrations, acoustic noise, and stray electromagnetic fields. Accordingly, it has been necessary to adopt rather elaborate precautions to isolate the two transducers and the traversing mechanism from these extraneous disturbances, using cabinets, sound-proof materials, foam-rubber pads, electromagnetic shielding, etc.

**Du Pont trademark*

Apparatus for fiber surface studies—Stanley C. Scheier.

Distribution of Flaws in a Monofilament Sample: A study was implemented during 1961 to use extreme-value statistics (which characterizes failure measurements) to deduce the distribution of weak spots or flaws in a monofilament from measurements of the distribution of rupture properties, as given experimentally by tensile breaking tests. Investigators in this field have noted the need for extensive experimental measurements to clarify the questions posed by theories. Particularly, the distribution of flaws in textile materials cannot be defined by the information now available in the general literature. Recent publications have raised the question of the character of this distribution, *i.e.*, whether it can be considered to be normal, Laplacian, or of some other form.

For the experimental phase of this investigation, two Celanese* acetate yarns having filaments of relatively high linear densities (17 and 50 den.) were obtained. Single-fiber specimens of the smaller sizes were prepared for testing at 1-, 3-, and 9-in. lengths, and specimens of the larger size, at 1-, and 3-in. lengths. Thus, either volume or length can be chosen as the controlled variable in a 2 x 2 array; linear density is the other controlled variable in this experimental design.

Breaking forces have been obtained on 480 specimens in each of the five categories. The variation in breaking force along the filaments, "down the spool," has been studied and found to be appreciable. However, statistical analysis has indicated a means of compensating for this variation. These corrections are currently underway. When this work is accomplished, the data will be in such form that the distribution of extremes, as represented by breaking force, can be analyzed.

Properties of Fiber Assemblies

A considerable portion of the TRI research program involves yarns and fabrics, but, for the most part, this research falls more logically within the scope of other headings. Thus, only three topics, specifically related to fiber assemblies, are reported here.

Studies of Nonwoven Fabrics: The objective of this program is to provide an analysis of the properties of air-lay, random-web types of nonwoven fabrics (bonded with thermoplastic fibers and needle-looming) in terms of the principal fiber and construction variables, using the "response surface" statistical approach. Fourteen variables were chosen for the program: linear density, staple length, crimp, and modulus of the base fiber; type, linear density, staple length, and modulus of the bonding fiber; weight ratio of base fiber to bonding fiber; mass per unit area of mat; number of needle-looming passes; temperature, pressure,

**Trademark of Celanese Corporation of America.*

Bat-forming apparatus for nonwoven fabric studies—Professor Whitwell and Research Fellow Winchester.

and duration of the bonding operation. The responses to be measured as functions of these variables are: reduced tensile strength, elongation at break, shape of the load–strain curve, stiffness, tear strength, hand, and abrasion resistance.

A "resolution-five" fractional factorial design was adapted to a multivariable investigation of these nonwoven fabrics. The experimental design proposed contemplates 16 blocks of 16 experiments each. Judicious selection of 8 of the 16 blocks allows complete resolution of the design in 128 experiments, with the following reservations: (1) Six selected main effects or two factor interactions must be assumed or known to be negligible; (2) all but 9 of the estimates must be nonorthogonal.

Special apparatus for forming the experimental samples was designed and built. This equipment deposits a uniform random web of dimensions 12 inch x 6 inch upon an oscillating screen by the air-lay principle. The apparatus, after considerable experimental work, is now satisfactory for short and intermediate staple length fibers, for example, 19/16 inch, 5.5 denier, low-crimp viscose staple. The equipment requires major modification to handle the longer staple fibers. Further experimental work with this necessary modification in mind is under way.

Properties of Steerhides and Constituent Collagen Fiber Aggregates: A limited amount of experimental work was done on collagen fibers and the steerhides from which they were taken, in order to clarify certain anomalies in the results obtained in connection with a government-sponsored program terminated in 1959. A hide may be considered as a natural nonwoven fabric with fibers disposed in a great variety of directions, depending upon the region of the hide chosen for study. Thus, an investigation of the properties of the collagen fiber aggregates in relation to hide properties has pertinence to the general problem of nonwoven fabrics.

Excellent correlation between the properties of the collagen fiber aggregates and those of the hides was found, when tanning was the independent parameter. The absolute values of the properties, ultimate tenacity and modulus, were lower and the ultimate strain was higher for the hides and leathers as compared to corresponding properties of the collagen fiber aggregates, in accord with experience with fabrics. The effects of moisture and tanning upon the properties of the collagen fiber aggregates were interesting in that they were comparable to those found in textile fibers and yarns.

Transverse Deformation of Grillages: Study of the problem of two filaments, crossed at 90° and loaded transversely, i.e., a simple grillage, provides basic information on the principles and procedures to be used in the analysis of more complex systems. Such an analysis is designed to help in predicting fabric behavior from the mechanical properties and the physical configuration of the constituent filaments. In this work at TRI, it was assumed that: (1) the filaments are of linearly elastic and homogeneous material; (2) the cross sections are circular and of constant diameter, small compared to filament length; and (3) there is no friction or constraint at the point of contact between filaments, i.e., the top filament is free to slide relative to the lower filament without being subjected to a moment due to friction. Large deflections were considered.

The nonlinear equations describing the equilibrium position of the system, in terms of the loading, properties of the filaments, and the dimensions, were obtained by the principle of minimum potential energy. Exact solutions of these equations are not known, and approximate methods give solutions unsatisfactory in certain respects. Thus the reversion method, which reduced the solution of the nonlinear equations to the solution of a set of linear differential equations, was applied. The resulting solutions appeared in the form of infinite series, but it was found that almost any type of external loading could be treated. The set of governing equations has been programmed, and solutions are being obtained using a high-speed computer at the Princeton facility of the Institute for Defense Analysis.

The apparatus designed to investigate the load–deformation behavior of complex grillages consists of a small wind tunnel to provide the aerodynamic loads, an hydraulic load cell to measure the drag on the grillage, and an optical deflection measuring device. A recently developed technique, photogrammetry, provides a contour map of the deflected grillage from a pair of stereophotographs. Advantages inherent in this method are: (1) the camera may be located where it will not affect the flow through the grillages; and (2) all deflection readings are taken simultaneously and thus there is no time effect on the response. On the basis of preliminary runs, it appears that the apparatus can be made to function as planned. Specimens of nylon, fiber glass, and steel will be tested.

Chemical Treatments of Cotton

Current interest in the modification of cotton by various chemical treatments has been anticipated by long-range studies at TRI. Work is in progress on the chemical and physical factors involved in improving the resilience of cotton to gain a deeper understanding of the complex phenomena involved in imparting minimum-care properties to cotton fabrics. A broad program on the chemical receptivity of cotton involves the relation of chemical response to fiber morphology and structure. The principles of nonaqueous swelling of cellulose are also being studied as part of an effort to enlarge the scope of chemical treatments.

Resilience of Chemically Modified Cottons: The results of previous studies in this program showed that methylene cross-links could be introduced into cotton cellulose by treating alkali cellulose and sodium cellulosate substrates with methylene dibromide. Treated fabrics with improved wet wrinkle recovery but unchanged dry wrinkle recovery were obtained. The reaction of formaldehyde with cotton under acid conditions was also investigated, and fabric samples exhibiting improved wet and dry wrinkle recovery were prepared. The mechanical behavior of single fibers withdrawn from the treated fabrics was examined under both wet and dry conditions of testing. Drastic reductions in fiber breaking tenacity and breaking extension were observed, whereas the fiber elastic modulus appeared unchanged by the treatments. The effect of cross-linking on fiber tensile properties could not be evaluated due to the fact that the reaction conditions were found to cause degradation that was especially severe in the case of the acid-catalyzed formaldehyde treatment. The results of measurements of single fiber resilience gave a qualitative correlation with the data obtained on the wrinkle recovery of the treated fabrics. Thus, in methylene dibromide-treated samples the wet resilience was improved but dry resilience was unchanged. In

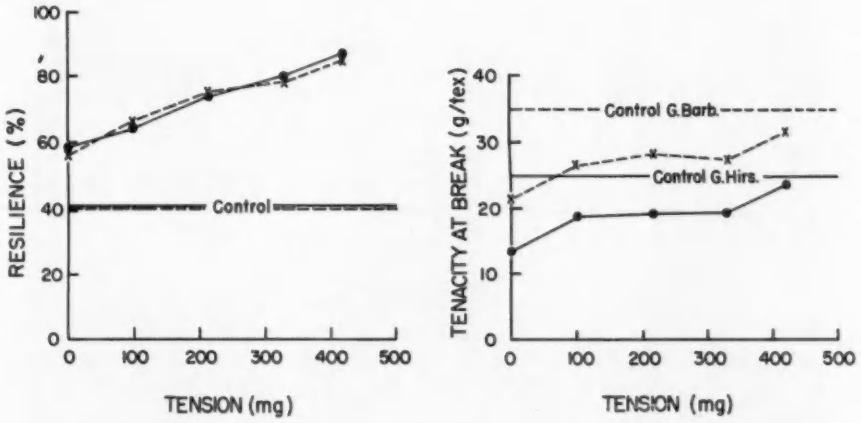
the case of the formaldehyde-treated samples, increases in both dry and wet fiber resilience were observed.

A program has been initiated involving a new cross-linking reaction for cellulose resulting in the introduction of disulfide cross-links. The reaction sequence has been established as a result of a study at TRI on model compounds, which also established the fact that only intermolecular cross-links could be formed with this system. The preferred reaction sequence for quantitative study involves the preparation of tosyl cellulose as the first step. The tosyl intermediate is then converted to a mercapto derivative (6-thiocellulose) followed by oxidation of the mercapto groups to disulfide cross-links. Cotton fabrics modified in this way showed excellent wet wrinkle recovery and slightly improved dry wrinkle recovery. Under the proper conditions fabrics could be modified by tosylation to fairly high substitution levels without any tensile losses. It is anticipated that the effect of cross-linking on mechanical properties can be unambiguously established. Preliminary experiments have shown that the disulfide cross-links can easily be cleaved by a mild reduction treatment without damage to the substrate. Wrinkle recovery has been reduced thereby to the original level and the cross-links have been re-formed by another oxidation treatment with concomitant improvement in wrinkle recovery.

Nonaqueous Swelling Agents for Cotton Cellulose: Any chemical treatment or modification of cotton requires at least minimal opening of the cellulose structure by swelling to mitigate the strictures imposed by the crystalline regions and by the hydrogen bonding of hydroxyl groups in the amorphous regions. Most chemical treatments of cotton employ aqueous media to obtain the requisite swelling. However, many potentially useful chemical modifications require nonaqueous reaction media and are not being properly exploited due to the noxious nature of the solvents required and/or the low efficiency of the solvents as swelling agents.

A variety of nonaqueous, organic solvents have been studied in an effort to establish the characteristics necessary for an efficient, nonaqueous swelling agent. The efficacy of these compounds as swelling agents was evaluated by measurements of (1) liquid imbibition, (2) dye uptake as estimated by a differential dye test, (3) yarn contraction, and (4) changes in single fiber length. A series of binary systems that comprised citric acid, glycerol, ethylene glycol or cyclohexanone in alcohols, ketones, and aliphatic acids proved effective in swelling cotton cellulose without concomitant damage to the cotton substrate. Results obtained with certain solvents suggested that molecular configuration and conformation may be as significant as compound functionality.

Resin-Finishing of Cotton: Previous work on the response of different cottons to identical chemical treatments, such as mercerization, has shown that the variations observed can be related to differences in fiber fine structure. In an extension of this study the effect of resin-finishing on cotton yarns revealed significant increases in the tensile properties and resilience of fibers when the yarns were treated under tension. However, due to the complex geometry of the yarn structure, the effects of tension on the cotton fiber response to the resin treatment could not be satisfactorily established by control of tension on the yarn. Therefore, individual fibers from six different cottons were resin-treated with dimethylol ethyleneurea (DMEU) under controlled and systematically varied conditions of tension. The treatment comprised immersion of the single fibers in aqueous DMEU solutions containing a magnesium chloride catalyst, drip-drying, and oven-curing. During the treatment the single fibers were tensioned under loads of from 0 to 420 milligrams. Significant changes were observed in the mechanical properties of the treated fibers, and these changes were found to be highly dependent upon the tension exerted. Fibers treated under high tensions exhibited the greatest increases in resilience and the greatest strength retention. The six cottons were found to respond differently to a particular treatment. As in the case of earlier work, these differences proved to be functions of the fibrillar orientation as estimated from x-ray angle measurements.

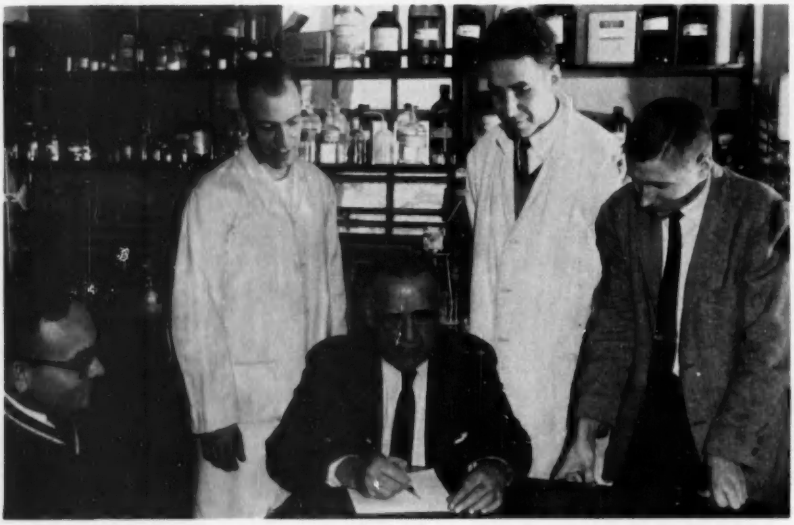


The effects of fiber tension on resilience and tenacity at break, during the treatment of a single cotton fiber with dimethylol ethylene urea resin.

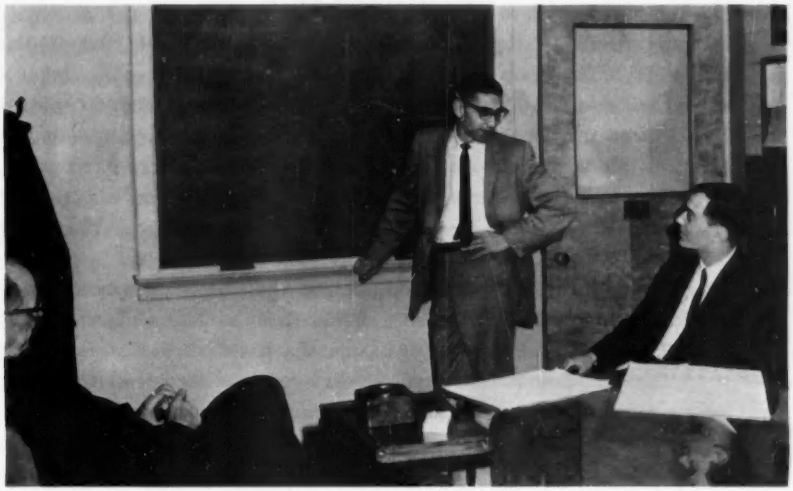
GRADUATE EDUCATION

The TRI program of graduate education conducted cooperatively with Princeton University is now in its 18th year of operation, and its success is clearly evidenced by the recognition it has received from leaders in education and industry. The function of TRI graduate education is to provide a group of scientists trained at the doctorate level who, through their research at TRI, have become interested in applying their basic scientific knowledge to fiber and textile problems. Alumni of our program may be found in industry and in academic laboratories where their ultimate contributions to fiber science are many and varied.

A Research Fellow's contribution to textile science does not begin with his employment in industry, at the completion of his doctoral training; rather it begins with the first day of his appointment as a TRI Research Fellow. The work done by our students under the able guidance of our distinguished group of Research Associates and administratively coordinated by Dr. L. Rebenfeld is an integral part of the Institute's research activities and results in many significant and pioneering contributions to textile science. It is noteworthy that since 1945 approximately one-half of the papers published by TRI have been authored or co-authored by Research Fellows. Frequently a group-supported project has evolved from a basic pioneering concept in textile science which constituted a doctoral dissertation. The graduate education program, therefore, forms the core of the Institute's research activity.



Professor Pacsu with (left to right) Research Fellows Lifland, Rivlin, Arendt, and Norling.



Mechanical engineering conference—Professor Suppiger with Research Fellows Regalbuto and Grover.

Research Fellows: Four Research Fellows have sustained their final examinations and thus have earned the Ph.D. degree from Princeton University: Dr. Richard E. Heitman, chemical engineer; Dr. William D. Freeston, mechanical engineer; Dr. Donald D. Kasarda, physical chemist; and Dr. Leonard Lifland, organic chemist. This brings to a total of 42 the number of men who have earned the Ph.D. degree as TRI Research Fellows since the program was initiated in 1945. Two other Fellows have submitted their dissertations during 1961, and we anticipate that Mr. Thomas J. Cochrane, Jr. and Mr. Robert P. Teulings, both in chemical engineering, will sustain their Final Public Oral Examination early in 1962.

Mr. Henry W. Saffer, an advanced graduate student in physical chemistry, is in the last stages of his research, conducted under the guidance of Professor Kauzmann. He will soon submit his dissertation to Princeton University. Mr. John A. Regalbuto is similarly in the last phases of his doctoral program in mechanical engineering, which is being supervised by Professor Suppiger. We anticipate that both of these men will soon be added to our ever increasing list of alumni. Mr. Elliot B. Grover, also an advanced graduate student in mechanical engineering, has begun preliminary consideration of his research, which will tend to clarify some of the theoretical aspects of fiber fatigue and will thus supplement the group-supported fatigue project. Mr. George T. Davis sustained the crucial General Examination in physical chemistry during 1961 and,

therefore, is now able to devote himself on a full-time basis to research on dyeing kinetics under the supervision of Professor Taylor. Mr. Volker D. Arendt and Mr. Jonathan B. Rivlin, both second-year graduate students in organic chemistry, have begun their research in cellulose chemistry under the guidance of Professor Pacsu. These men still face the General Examination, as does Mr. Gordon D. Moskowitz, a second-year graduate student in mechanical engineering.

We are very pleased to have added to our group of Research Fellows two first-year graduate students: Mr. Parry M. Norling, who is majoring in chemistry, and Mr. Samuel C. Winchester, Jr., who is majoring in chemical engineering. Mr. Norling is an alumnus of Harvard University where he was a student in the physical sciences program, while Mr. Winchester received undergraduate degrees in chemical engineering and applied mathematics from North Carolina State College. Both of these men have begun consideration of their research topics, Mr. Norling working under the guidance of Professor Tobolsky, and Mr. Winchester under the direction of Professor Whitwell.

It is a pleasure to report that our active TRI Research Fellows are performing satisfactorily in their academic studies at Princeton University and that they are pursuing their research in a diligent manner at TRI. These men have chosen research assignments which should add significantly to our understanding of the chemistry and physics of fibers and fiber systems. We hope that in future years we shall be able to continue to attract to our unique program fellowship candidates with the necessary qualifications for advanced study and the required special interest in textile research that have been demonstrated by our students during the past year.

Postdoctoral Fellows: A significant expansion in our postdoctoral fellowship program has been brought about during 1961 with a view toward strengthening the Institute's fundamental research activities in several areas. While the TRI postdoctoral effort is an activity of the education program, the research undertaken by this group of senior scientists is wholly integrated with the Institute's over-all research effort.

Dr. Dusan Prevorsek, appointed a Postdoctoral Fellow in 1961, has assumed the scientific responsibilities of our group-supported fiber fatigue project under the direction of Dr. Lyons. Dr. Prevorsek is a physical chemist who has had extensive experience in polymer research, both in universities and in industry.

Dr. Hans-Dietrich Weigmann, an organic chemist with experience in protein chemistry, joined our staff to become a senior scientist on our wool project under the direction of Dr. Rebenfeld. Dr. Weigmann's previous work in wool chemistry was done under Prof. Helmut Zahn at the famous Wool Research Institute in Aachen, Germany.

Dr. Leonard Lifland, one of our own TRI Research Fellows, has accepted a postdoctoral assignment to work on our group-supported project on the resilience of chemically modified cotton, directed by Mr. Schwenker. Dr. Lifland's experience in cellulose chemistry while a graduate student made him an ideal choice for this important assignment.

We are pleased that Dr. V. D. Gupta, Assistant Professor in Physics at the University of Allahabad in India, has found it possible to accept a TRI postdoctoral fellowship for another year, thus enabling him to continue his important work on polymer structure with Professor Tobolsky, which he began in 1960. Several papers of far reaching significance have already resulted from his studies. Also working under Professor Tobolsky is Dr. Takashi Shibukawa, a TRI Visiting Postdoctoral Fellow, who joined the Institute in 1961. Dr. Shibukawa is an experienced polymer chemist on leave of absence from the Japan Exlan Company.

We are pleased to report that these men have taken on their assignments during 1961 with enthusiasm and diligence and that their contributions to the Institute's research activities are already numerous and significant. We are hopeful that during 1962 it will be possible to expand the postdoctoral fellowship program.

"Knight Work"—Sir Hugh Taylor with Research Fellows Saffer (standing) and Davis (seated).

Fellowship Grants: During 1961 six of our predoctoral Research Fellows were designated as recipients of special fellowships which were established at TRI by six companies who desired to support the education program directly. An attempt is made to keep the donor abreast of the student's progress. Research Fellows assigned to sponsored fellowships and the respective donors were as follows:

VOLKER D. ARENDT	Cone Mills Corporation
GEORGE T. DAVIS	The Celanese Corporation of America
PARRY M. NORLING	U.S. Rubber Company Foundation
JONATHAN B. RIVLIN	Courtaulds, Inc.
HENRY W. SAFFER	Union Carbide Chemicals Company
SAMUEL C. WINCHESTER, JR.	Johnson & Johnson

TRI's *Man of the Year,* Roy (Rocky) De Veto.

DISSEMINATION FUNCTIONS

Publications Department: *Textile Research Journal,* principal responsibility of the Institute's Publications Department, has maintained its place among the world's scientific periodicals. A modest backlog of manuscripts submitted for publication has developed in recent years and this is healthy in that it gives latitude to accept only first-class scientific papers, after thorough scrutiny by impartial reviewers. The time elapsing between acceptance and publication of papers has not increased significantly, however; it now averages about 4 months, as compared to 10-12 months in many scientific periodicals of this country.

It can be safely assumed that the number of acceptable papers submitted will continue to grow. Thus, we may find it necessary to increase the number of pages printed (1084 pages in 1961), thereby increasing our costs. Printing and mailing costs are also bound to continue their upward trend. It would seem that in order to maintain our publications operation "just in the black," as has been the case for the past three years, we may need to consider adoption of a "page charge" to authors, in accord with the long-established practice of the American Institute of Physics. A similar practice is contemplated for the journals of the American Chemical Society.

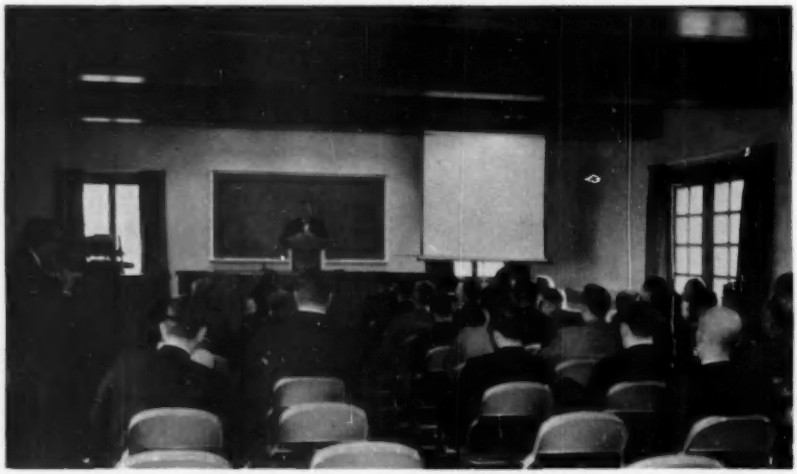
The page charge to authors seems to have ample justification on the basis that publication is an important part of research and thus its cost should be included in the total cost of any research program. Undoubtedly, the desirability of imposing a page charge will be a matter for consideration by the Advisory Committee on Publications in 1962.

Professor Richard K. Toner has continued his fine work as Director of Publications, ably assisted by Mrs. Dorothy Hollmann, Production Editor. Professor Toner also edits *Notes on Research,* which have continued to flow regularly to the

RICHARD K. TONER
Director of Publications

Active Membership. Only one issue of *Institute Membership News* was published in 1961. This news bulletin is not the responsibility of the Publications Department and it has become apparent that some individual member of the staff, other than the President, must be made responsible for its publication, if it is to appear on a regular basis.

Seminars and Meetings: Attendance at TRI Seminars, held biweekly during the academic year, has continued to grow. An excellent program was provided in 1961, under the supervision of Dr. Rebenfeld (see Appendix). These informal Seminars serve the dual function of placing important research findings before industrial scientists for discussion and of keeping TRI staff and Fellows abreast of scientific developments.



TRI Seminar

The Thirty-First Annual Meeting, held on March 16-17, was comparable to previous conclaves in quality of papers and their presentation. Topics of the technical sessions were widely varied—automatic doffing, reactive dyeing, tire cord fatigue, new fibers, etc. (See Appendix). The luncheon addresses: *Research Trends in the Pulp and Paper Industry* by Lincoln R. Thiesmeyer, President of the Pulp and Paper Research Institute of Canada and *What About These Soaring Sixties?* by Dexter Merriam Keezer, Economic Advisor to the McGraw-Hill Publishing Company, were both informative and entertaining.

Appendix

FINANCIAL STATEMENTS	44
COMPANY MEMBERS (during 1961)	47
PERSONAL MEMBERS	48
TRI PERSONNEL (as of December 31, 1961)	50
DISSERTATION RESEARCH OF PREDOCTORAL FELLOWS	51
SPONSORED PROJECTS	52
NOTES ON RESEARCH	55
PAPERS PUBLISHED	56
PAPERS PRESENTED	57
DOCTORAL DISSERTATIONS	58
MASTER'S THESIS	58
PATENTS	59
TRI SEMINARS	59
STAFF PROFESSIONAL ACTIVITIES	60
PROGRAM—31st ANNUAL MEETING	60

TEXTILE RESEARCH INSTITUTE

STATEMENT OF INCOME AND EXPENSES AND OPERATING DEFICIT

FOR THE YEAR ENDED DECEMBER 31, 1961

OPERATING INCOME AND EXPENSES:		
General income and expenses:		
Membership dues (less $13,426 allocated to Publications Department)	$ 98,612	
Special contributions (research fellowships)	23,750	
General income	122,362	
Less general program expenses (research and graduate education)	114,082	$ 8,280
Group supported projects:		
Income	164,282	
Expenses	164,444	(162)
Individually supported projects:		
U. S. Government:		
Income	66,707	
Expenses	73,772	(7,065)
Non-government:		
Income	25,699	
Expenses	27,067	(1,368)
Publications Department:		
Income	67,813	
Expenses	65,495	2,318
EXCESS OF OPERATING INCOME OVER OPERATING EXPENSES		2,003
OTHER INCOME		4,101
EXCESS OF INCOME OVER EXPENSES		$ 6,104
OPERATING DEFICIT, January 1, 1961		$139,187
DEDUCT EXCESS OF INCOME OVER EXPENSES AS FOLLOWS:		
Income	$450,964	
Expenses	444,860	6,104
Remainder		133,083
SURPLUS CREDIT—Adjustment relating to projects completed in prior years		1,554
OPERATING DEFICIT, DECEMBER 31, 1961		$131,529

The Notes to Financial Statements should be considered in connection with this statement.

TEXTILE RESEARCH INSTITUTE

Balance Sheet, December 31, 1961

ASSETS			LIABILITIES		
GENERAL FUNDS					
Cash		$51,902	Accounts Payable		$10,692
Accounts Receivable:			Unappropriated Textile Foundation Grant		49,060
U. S. Government	$24,837		Unexpended Project Receipts		72,783
Other	8,784	33,621	Deferred Dues, Subscriptions, Etc.:		
Supply Inventory—At average cost		5,570	Membership dues	$55,795	
Deferred Charges, Etc.		4,918	Subscriptions	23,585	
			Fellowship Grants	15,625	95,005
			Operating Deficit		(131,529)
	Total	$96,011		Total	$96,011
PROPERTY FUNDS					
Cash		$ 9,823	Accounts Payable		$ 3,757
Property—At cost:			Mortgage Payable		14,701
Land and improvements	$ 22,578		Property Funds Principal (See Note 2)		313,031
Buildings and improvements	213,685				
Laboratory equipment and tools	143,882				
Furniture, fixtures, etc.	55,887				
Total property	436,032				
Less accumulated depreciation since January 1, 1956	114,366	321,666			
	Total	$331,489		Total	$331,489

The Notes to Financial Statements should be considered in connection with this balance sheet.

TEXTILE RESEARCH INSTITUTE

NOTES TO FINANCIAL STATEMENTS
FOR THE YEAR ENDED DECEMBER 31, 1961

1. Income from dues, subscriptions, and fellowships is recorded, with minor exceptions, only as received and deferred to the extent of any prepayment thereof. Project income is accrued only to the extent of the recoverable unreimbursed expenditures applicable thereto, or deferred to the extent of the unexpended balances.

2. Property fund principal increased in the amount of $240 during the year representing a contribution to the library.

ACCOUNTANT'S OPINION

We have examined the balance sheet of Textile Research Institute as of December 31, 1961 and the related statement of income and expenses and operating deficit for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, such financial statements present fairly the financial position of the Institute at December 31, 1961 and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

Newark, N.J.
March 5, 1962

HASKINS & SELLS
Certified Public Accountants

COMPANY MEMBERS

(during 1961)

Ahmedabad Textile Industry's Research Association
Albany Felt Company[1, 2]
Althouse Chemical Company
American Association of Textile Chemists and Colorists
American Cyanamid Company[4, 5]
American Viscose Corporation[4, 5]
Arkansas Company, Inc.

Bachmann Uxbridge Worsted Company
The Barre Wool Combing Company, Ltd.[1]
Belding Heminway Company, Inc.

Geo. W. Bollman & Co., Inc.[1]
John H. Breck, Inc.[1]
Bryant Chemical Corporation
Burlington Industries, Inc.[1, 4]

Cascade Woolen Mill
Celanese Corporation of America[2, 5, 7]
The Chemstrand Corporation[2, 5]
Sté. Chimiotex
CIBA Corporation
Clemson Agricultural College, School of Textiles
Coats & Clark Inc.[3, 5]
Cold Spring Bleachery
Colgate-Palmolive Company
Cone Mills Corporation[3, 4, 7]
Corn Industries Research Foundation, Inc.
The Cotton Research Committee of Texas
Courtaulds (Alabama) Inc.[7]
Cranston Print Works Company[2, 4]

Dan River Mills, Incorporated
Deering Milliken Research Corporation[1, 2, 4]
W. J. Dickey & Sons, Inc.
The Dow Chemical Company
E. F. Drew & Co., Inc.
Drycor Felt Company
Dunlop Research Centre[5]
E. I. du Pont de Nemours & Co., Inc.[2, 5]

Eastman Chemical Products, Inc.
Evans Research & Development Corp.

Fabric Research Laboratories, Inc.[3]
Fibertest Inc.
FMC Corporation

General Electric Company
The General Tire & Rubber Company
Georgia Institute of Technology, A. French School of Textiles
The Gillette Company[1]
Otto Goedecke, Inc.
J. B. Goldberg

The Harodite Finishing Company, Inc.
The Hart Products Corporation
Hercules Powder Co., Inc.
Huyck Felt Co.[1]

Industrial Cellulose Research Limited
Industrial Rayon Corporation

Joanna Cotton Mills Company[3]
Johnson & Johnson[3, 7]

Kimberly-Clark Corporation[6]

Lowell Technological Institute Research Foundation
M. Lowenstein, Inc.[4]

Marriner Combing Company[1]
C. H. Masland & Sons
Otto B. May, Inc.
Mohasco Industries, Inc.
Philip Morris Incorporated

National Aniline Division, Allied Chemical Corp.[5]
National Cotton Council of America[2, 4]
Nopco Chemical Company[7]
North Carolina State College, School of Textiles[3]

Pepperell Manufacturing Company, Inc.[3, 4]
Philadelphia College of Textiles and Science
The Procter & Gamble Company

Quaker Chemical Products Corporation[4]

Riegel Textile Corporation[3]

Rohm & Haas Company[4]

Saco-Lowell Research & Development Center
Scholler Brothers, Inc.

Eugene W. K. Schwarz, Inc.
Standard Chemical Products, Inc.[2, 3, 4]
J. P. Stevens & Company, Inc.[1, 3, 4, 5]

Tennessee Eastman Company

Union Carbide Chemicals Company[2, 4, 7]

United States Rubber Company[5, 7]
United States Testing Company[3]

Warner-Lambert Research Institute[1]
Wellman Combing Company
The Wool Bureau, Inc.[1, 2]

FOOTNOTES:

Project Participation and Fellowship Support

1. The Permanent Set and Supercontraction of Keratin Fibers
2. Fiber Surface Studies
3. Industry Cotton Research Project
4. The Resilience of Chemically Modified Cottons
5. Fatigue in Textile Fibers
6. The Chemical Reactivity of Cellulose and Cellulose Derivatives
7. Fellowship Donor

PERSONAL MEMBERS

HONORARY FELLOWS

William D. Appel
Frederic Bonnet
Herbert Hoover
Hugh S. Taylor

LIFE

William D. Appel
A. G. Ashcroft
Lyman D. Briggs
Vannevar Bush
Donald Comer
Edward U. Condon
Donald H. Powers
Hugh S. Taylor
Rhett Y. Winters

INDIVIDUAL

Norman J. Alexander
Robert L. Amsler
Gregory Arapakis
Leslie Balassa
Clifford Bastuscheck
John Baymiller
C. W. Bendigo
Eugene Bernat
Gerson J. Bernstein
Clark G. Berry
S. Martin Billett
John A. Bilton
Domenico Bosco
Marcel Bovyn
Joseph H. Brant
Robert H. Brown
H. T. Buckley
R. F. Caroselli
P. J. G. Carrothers
V. Lindsay Chase
E. H. Clayton
Sanford L. Cluett
Sidney Cohen
Thomas D. Cole
Sherman Converse
Louis B. Cook
Jacques Corbiere
P. W. Cunliffe
J. Ellwood Currah
William F. Danner
W. G. Dicks
Helen Dikeman
Erb N. Ditton
Chimanlal Harilal Doshi
John H. Draper, Jr.
J. Dunkerley
Francois Ecochard
Sidney M. Edelstein
Rachel Edgar
Hugo Ehrhardt
J. P. Elting
Herman Epstein
Vincent Evart-Chmielnicki
David Fields
Lucille Finley
John Fox
Freeman W. Fraim
George M. Gantz
George Garcelon
J. F. Gaunt
R. C. Geering
Robert L. Goldemberg
A. C. Goodings
Robert Graham
J. F. Gschwind
Martin H. Gurley, Jr.
William H. Hagenbuch
John N. Hall
Emanuel Hatzopoulos
M. Earl Heard
Max R. Held
H. G. Hencken
Julian T. Hightower
Harold E. Hirsch
Joseph E. Hoesl
H. Hofmann
Giles E. Hopkins
David E. Howe
P. S. Howe, Jr.
J. L. Isenring
Thomas A. Jamieson
Albert E. Johnson
Louis L. Jones, Jr.
P. J. Kangle
R. C. D. Kaushik
Emil J. Kayser
C. S. Kemic
S. J. Kennedy
Maurice G. Kramer
Jules Labarthe
Lewis Larrick
Lawrence C. Leatherland
T. B. Lefferdink

S. Clark Lilley
Louis F. Luechauer
S. B. McFarlane
Pauline Beery Mack
W. C. MacMillan
G. D. Mallory
H. F. Mark
John E. Masters
William C. Menzies, Jr.
R. E. Miskelly
C. J. Monego
Donald J. Montgomery
Leon E. Moody
Edwin Morgan
Henry M. Morgan
Donald R. Muir
John S. Murray
Raymond P. Nordheim
Arthur R. Olson
Gordon Osborne
Warley L. Parrott
Edward C. Pfeffer, Jr.
Raymond A. Pingree
J. J. Press
Malcolm J. Reider
Walter H. Ridley
Elliot Rosengarten
Karl T. Schaefer
David C. Scott, Jr.
H. A. Secrist
Norman L. Seltzer
John R. Seydel
W. S. Shaw
H. G. Simonds
Sidney G. Smith, Jr.
Harry C. Spatz
Donald H. Spitzli
S. Srikantiah
Deane F. Stahmann
Richard B. Stehle
L. Stevens
William J. Stewart
Sabbat J. Strianse
H. Michael Strub, Jr.
Robert L. Stutz
George B. Suhrie
William F. Sullivan
D. V. Muni Swamy
Edward L. Taylor
Saul Tessler
M. Fred Thoma
Dewey T. Thompson
W. F. Underwood
George A. Urlaub
Boris Uzenoff
Emery I. Valko
A. Van Der Woude
A. W. Vint
Kyle Ward, Jr.
Mark Weisberg
Richard D. Wells
Herbert L. Werner
Eric Weyl
Howard J. White, Jr.
Vivian White
Ross Whitman
Melvin Wiener
John T. Wigington
Charles C. Wilson
P. J. Wood
W. S. Woodson, Jr.
Lawrence L. Wyss
W. M. Yow
George F. Zealand
William Zimmerman

ASSOCIATE

Norman C. Armitage
Herbert J. Ball
F. W. Bauer
Philip T. Bodell
Alfred K. Bonge
Allan L. Brassell
William F. Brommelsiek
George S. Buck, Jr.
Alfred A. Burgeni
Miles A. Dahlen
S. Jack Davis
John H. Dillon
Nicholas Drisch
Virginia L. Duncan
Joseph H. Dusenbury
Lyman E. Fourt
R. J. Franz
E. Friderici
Donald J. Gale
Charles F. Goldthwait
Robert M. Hoffman
George H. Hotte
Julian S. Jacobs
Hayden B. Kline
John F. Krasny
Richard T. Kropf
Kermit S. LaFleur
G. K. Lake
Joseph B. Levy
W. James Lyons
John Menkart
David Milne
J. Fred Murray
Eugene Pacsu
Edgar J. Page
E. V. Painter
Charles S. Parsons
Russell W. Peterson
J. B. Quig
Ludwig Rebenfeld
H. Repokii
Elbert B. Roberson, Jr.
Bruno R. Roberts
William J. Roberts
A. D. Rosenberg
Stanley E. Ross
J. M. Salsbury
T. C. Sayers
Ralph G. Schaubhut
Webster R. Schmidt
R. J. G. Schofield
Arthur G. Scroggie
Richard E. Seaman
W. Bailey Sellars
D. Shichman
L. S. Sinness
Leonard Smith
Leonard Soep
Harry E. Stanley
Richard O. Steele
C. R. Stock
E. W. Suppiger
F. H. Swezey
Giuliana C. Tesoro
D. Bruce Thornton
Richard K. Toner
T. Vickerstaff
Werner von Bergen
Robert E. Wagner
James H. Wakelin
Charles Weidmann
O. C. Wetmore
John C. Whitwell
Robert W. Work

STUDENT

Volker D. Arendt
Jin Wook Chung
G. Thomas Davis
Elliot B. Grover
G. D. Moskowitz
Takajuki Murayama
Parry M. Norling
John A. Regalbuto
Jonathan B. Rivlin
Henry W. Saffer
Samuel Winchester
Bahram E. Yazdani

TRI PERSONNEL (as of December 31, 1961)

President John H. Dillon, Ph.D., F.T.I., physicist
Secretary-Treasurer Paul C. Alford, Jr.

RESEARCH AND EDUCATION

Associate Research Directors

W. James Lyons, Ph.D., physicist
Ludwig Rebenfeld, Ph.D., F.T.I., chemist
Robert F. Schwenker, Jr., A.B., chemist

Research Associates

Walter J. Kauzmann, Ph.D., chemist
Eugene Pacsu, Ph.D., chemist
Edward W. Suppiger, Ph.D., mechanical engineer
Hugh S. Taylor, K.B.E., D.Sc., LITT.D., LL.D., F.R.S., chemist
Arthur V. Tobolsky, Ph.D., chemist
John C. Whitwell, Ch.E., chemical engineer

Senior Scientists

Karin Beurling, M.S., chemist
Arthur B. Coe, B.S., microscopist
Cornelia Dansizer, B.S., chemist
V. D. Gupta, Ph.D., physicist (Postdoctoral Fellow)
Leonard Lifland, Ph.D., chemist (Postdoctoral Fellow)
Dusan Prevorsek, Ph.D., chemist (Postdoctoral Fellow)
Stanley C. Scheier, M.S., engineer
Takashi Shibukawa, Ph.D., chemist (Visiting Postdoctoral Fellow)
Hans-Dietrich Weigmann, Ph.D., chemist (Postdoctoral Fellow)

Junior Scientists and Research Assistants

Louis R. Beck, Jr., B.S.
Marna Garwood, B.A.
Edward B. Jeffries
Kay Morrison, B.S.
Marjie G. Scott, M.S.
Rudolph Turner, B.S.
Polly K. Way
Robert K. Zuccarello, A.A.

Research Fellows

Volker D. Arendt, B.S.
George T. Davis, B.Ch.E.
Elliot B. Grover, M.S.
Gordon D. Moskowitz, B.M.E.
Parry M. Norling, A.B.
John A. Regalbuto, M.S.E.
Jonathan B. Rivlin, B.S.
Henry W. Saffer, M.S.
Samuel C. Winchester, Jr., B.S.

PUBLICATIONS DEPARTMENT

Richard K. Toner, Ph.D., Director of Publications
Dorothy D. Hollmann, A.B., Production Editor
Julian S. Jacobs, B.Sc., Consultant

ADMINISTRATIVE AND SERVICE DEPARTMENT

Bertha F. Golden, Administrative Assistant
Anne B. Mansfield, A.B., M.L.S., Librarian
Joan Umpleby, Accountant
Harold Lambert, Mechanician
Joshua Higgins, Storekeeper
Noel Meyer

Secretarial and Clerical

Audrey Bennett
Christine Peakes
Helen Tornell
Elizabeth Vollrath
Eleanor Wills

Maintenance

Roy De Veto
Rubin Rodriguez
William Ryan

DISSERTATION RESEARCH OF PREDOCTORAL FELLOWS

Optical Rotatory Dispersion Studies of Soluble Wool Proteins, HENRY W. SAFFER, Advanced Graduate Student in Physical Chemistry (Union Carbide Chemicals Co. Fellow). Advisor: Prof. Walter J. Kauzmann.

Transverse Deformation of Grillages, JOHN A. REGALBUTO, Advanced Graduate Student in Mechanical Engineering. Advisors: Prof. Edward W. Suppiger and Dr. John H. Dillon.

Dynamic Properties of Filaments in Fatigue, ELLIOT B. GROVER, Advanced Graduate Student in Mechanical Engineering. Advisor: Prof. Edward W. Suppiger.

Studies in the Kinetics of Dyeing, GEORGE T. DAVIS, Second-year Graduate Student in Physical Chemistry (Celanese Corporation of America Fellow). Advisor: Prof. Hugh S. Taylor.

Study of End-groups in Methylated Cellulose, VOLKER D. ARENDT, Second-year Graduate Student in Organic Chemistry (Cone Mills Corporation Fellow). Advisor: Prof. Eugene Pacsu.

Location of Cross-links and Other Substituents in Certain Derivatives of Cellulose, JONATHAN B. RIVLIN, Second-year Graduate Student in Organic Chemistry (Courtaulds Inc. Fellow). Advisor: Prof. Eugene Pacsu.

Mechanical Engineering Studies of Textile Materials, GORDON D. MOSKOWITZ, Second-year Graduate Student in Mechanical Engineering. Advisor: Prof. Edward W. Suppiger.

Studies of Nonwoven Fabrics, SAMUEL C. WINCHESTER, JR., First-year Graduate Student in Chemical Engineering (Johnson & Johnson Fellow). Advisor: Prof. John C. Whitwell.

Mechanism of Polypropylene Oxidation, PARRY M. NORLING, First-year Graduate Student in Organic Chemistry (U. S. Rubber Co. Foundation Fellow). Advisor: Prof. Arthur V. Tobolsky.

SPONSORED PROJECTS

PERMANENT SET AND SUPERCONTRACTION OF KERATIN FIBERS

Period of Support: 3 years ending November 30, 1962
Approximate Total Support Level: $89,000

L. Rebenfeld, *Project Director*
Cornelia Dansizer
Hans-Dietrich Weigmann

Sponsors:
Albany Felt Company
The Barre Wool Combing Company Ltd.
Geo. W. Bollman & Co., Inc.
John H. Breck, Inc.
Burlington Industries, Inc.
Deering Milliken Research Corporation
Harris Research Laboratories, Inc. (The Gillette Company)
Huyck Felt Corporation
Marriner & Co., Inc.
J. P. Stevens & Co., Inc.
Warner-Lambert Research Institute
The Wool Bureau, Inc. (International Wool Secretariat)

INDUSTRY COTTON RESEARCH PROJECT

Period of Support: 5 years ending August 31, 1961
Total Support Level: $131,000

L. Rebenfeld, *Project Director*
Polly K. Way

Sponsors:
The American Thread Company, Inc.
Coats & Clark Inc.
Cone Mills Corporation
Fabric Research Laboratories, Inc.
Joanna Cotton Mills Company
Johnson & Johnson
North Carolina State College, School of Textiles
Pepperell Manufacturing Company, Inc.
Riegel Textile Corporation
Standard Chemical Products, Inc.
J. P. Stevens & Company, Inc.
United States Testing Company

RESILIENCE OF CHEMICALLY MODIFIED COTTONS

Period of Support: 6 years ending November 30, 1964
Total Support Level: $237,600

R. F. Schwenker, Jr., *Project Director*
Edward B. Jeffries
Leonard Lifland
Robert Zuccarello

Sponsors:
American Cyanamid Company
American Viscose Corporation
Burlington Industries, Inc.
Cone Mills Corporation
Cranston Print Works Company
Deering Milliken Research Corporation
Foundation for Cotton Research and Education
M. Lowenstein & Sons, Inc.
Pepperell Manufacturing Company, Inc.
Quaker Chemical Products Corp.
Rohm & Haas Company
Standard Chemical Products, Inc.
J. P. Stevens & Co., Inc.
Union Carbide Chemicals Company, Div. of Union Carbide Corporation

FATIGUE IN TEXTILE FIBERS

Period of Support: 5½ years ending April 30, 1964
Total Support Level: $192,300

W. James Lyons, *Project Director*
Kay Morrison
Dusan Prevorsek

Sponsors:
Allied Chemical Corporation
American Cyanamid Company
American Viscose Corporation
Celanese Corporation of America
The Chemstrand Corporation
Coats & Clark Inc.
Dunlop Research Centre
E. I. du Pont de Nemours & Co., Inc.
United States Rubber Company, Textile Division
J. P. Stevens & Co., Inc.

FIBER SURFACE STUDIES

Period of Support: 3 years ending August 31, 1963
Approximate Total Support Level: $90,150

W. James Lyons, *Project Director*
Stanley C. Scheier

Sponsors:
Albany Felt Company
Celanese Corporation of America
The Chemstrand Corporation
Cranston Print Works Company
Deering Milliken Research Corporation
E. I. du Pont de Nemours & Co., Inc.
National Cotton Council of America
Standard Chemical Products, Inc.
Union Carbide Chemicals Company, Div. of Union Carbide Corporation
The Wool Bureau, Inc.

THE CHEMICAL REACTIVITY OF CELLULOSE AND CELLULOSE DERIVATIVES

Period of Support: 3 years ending February 28, 1962
Total Support Level:
Sponsor: Kimberly-Clark Corporation

Robert F. Schwenker, Jr., *Project Director*
Karin Beurling
Rudolph Turner
Robert Zuccarello

FLAME-RESISTANT PARACHUTE PACK MATERIAL

Sponsor: Wright Air Development Division
Period of Support: approximately 16 months ending June 30, 1961
Total Support: $26,619
Chief Investigator: Robert F. Schwenker, Jr.
Robert K. Zuccarello

THERMAL CHARACTERISTICS OF COATED TEXTILE FABRICS

Sponsor: U. S. Navy Supply Research and Development Facility, Clothing and Textile Division
Period of Support: 5 years ending August 31, 1961
Total Support: $88,005
Chief Investigator: Robert F. Schwenker, Jr.
Louis R. Beck, Jr.

A SYSTEMATIC INVESTIGATION OF NONAQUEOUS SWELLING AGENTS FOR CELLULOSE TO PROVIDE NEW CHEMICAL AND PHYSICAL MODIFICATIONS OF COTTON

Sponsor: Agricultural Research Service, U. S. Department of Agriculture
Period of Support: 2 years ending June 19, 1962
Total Support: $46,805
Chief Investigator: Ludwig Rebenfeld
Marjie G. Scott
Polly K. Way

MONOGRAPH ON IMPACT PHENOMENA IN TEXTILES

Sponsor: Quartermaster Research and Engineering Command, Department of the Army
Period of Support: 3 years 3 mos. ending December 29, 1961
Total Support: $24,874
Chief Investigator: W. James Lyons

RESILIENCE OF FIBERS

Sponsor: Office of Naval Research
Period of Support: 12 years ending May 31, 1963
Total Support: $210,600
Chief Investigator: John H. Dillon
V. D. Gupta
T. Shibukawa
A. V. Tobolsky
Rudolph Turner

NOTES ON RESEARCH*

126. Evidence for the Existence of Three Different Free Hydroxyl Groups in Acetone-Soluble Cellulose Acetate, MAKOTO YANAKA and L. REBENFELD.

127. Some Aspects of Fatigue in Cyclic Tension, W. JAMES LYONS.

128. Quantitative Techniques Applied to the Differential Dyeing Test for Cotton Maturity and Structure, L. REBENFELD.

129. Molecular Conformation in Oriented Fibers, V. D. GUPTA with A. V. TOBOLSKY and J. H. DILLON.

130. Fatigue of Nylon Monofils in Biaxial Rotation, W. JAMES LYONS and ARTHUR B. COE.

131. Interaction between 2-Thiobarbituric Acid and Cotton, L. REBENFELD.

*Available only to TRI Company Members.

PAPERS PUBLISHED

The Absorption of a Disperse Dye by Cellulose Acetate in the Presence and Absence of Butanol, ELIZABETH P. TEULINGS and HOWARD J. WHITE, JR., *Textile Research J., 31,* 52-56 (January).

Response of Cottons to Chemical Treatments. Part I: Fiber Mercerization and Urea Treatments, L. REBENFELD, *Textile Research J., 31,* 123-130 (February).

Response of Cottons to Chemical Treatments. Part II: Yarn Mercerization, L. REBENFELD, *Textile Research J., 31,* 253-257 (March).

Response of Cottons to Chemical Treatments. Part III: Yarn Resin Finishing, L. REBENFELD, *Textile Research J., 31,* 311-316 (April).

Evidence of the Existence of Three Different Free Hydroxyl Groups in Acetone-Soluble Cellulose Acetate, MAKOTO YANAKA and L. REBENFELD, *J. Polymer Sci., 50,* S38-S39 (April).

Vibration of Stepped Beams, N. J. TALEB and E. W. SUPPIGER, *J. Aeronaut. Sci., 28,* 295-298 (April).

Fiber Properties Affecting Mills, L. REBENFELD, *Cotton Gin & Oil Mill Press, 62,* no. 11, 24-25 (May).

Preparation and Characterization of Sodium Cellulosates, ROBERT F. SCHWENKER, JR., TETSUO KINOSHITA, KARIN BEURLING, and EUGENE PACSU, *J. Polymer Sci., 51,* 185-198 (May).

Determination of Molecular Weight Distribution in Polyvinyl Acetate by Selective Adsorption Technique, P. J. KANGLE and EUGENE PACSU, *J. Polymer Sci., 54,* 301-320 (October).

A Quantitative Study of Differential Dyeing of Cotton as a Means of Elucidating Fiber Structure, L. REBENFELD and HONG WU, *Textile Research J., 31,* 886-892 (October).

Molecular Conformation in Oriented Fibers (Letter), A. V. TOBOLSKY and V. D. GUPTA, *Textile Research J., 31,* 913-914 (October).

Reduced Designs of Resolution Five, JOHN C. WHITWELL and GRAHAM K. MORBEY, *Technometrics, 3,* 459-477 (November).

The Resilience of Chemically Modified Cottons. I. Reactions of Alkali Cellulose and of Sodium Cellulosates with Methylene Dibromide, W. LOBUNEZ and J. H. DUSENBURY, *J. Appl. Polymer Sci., 5,* 686-703 (November/December).

The Resilience of Chemically Modified Cottons. II. Reactions of Cellulose with Formaldehyde under Acid Conditions, J. H. DUSENBURY, E. PACSU, E. P. TEULINGS, and W. LOBUNEZ, *J. Appl. Polymer Sci., 5,* 704-713 (November/December).

A Study of the Interaction between 2-Thiobarbituric Acid and Cotton, L. REBENFELD, *Textile Research J., 31,* 1019-1025 (December).

The Kinetics of the Absorption and Desorption of Single Ions by Keratin Fibers, DONALD L. UNDERWOOD and HOWARD J. WHITE, JR., *Textile Research J., 31,* 1054-1057 (December).

PAPERS PRESENTED

Evolutionary Operations, presented by JOHN C. WHITWELL at a joint meeting of the American Society for Quality Control and the American Institute of Chemical Engineers, Akron, Ohio, January 12.

Differential Thermal Analysis of Polymeric Materials, presented by ROBERT F. SCHWENKER, JR. at the Research Seminar Program, Rohm & Haas Company, Bristol, Pennsylvania, February 21.

Studies of Wool Fibers Relating to Minimum-Care Applications, presented by JOSEPH H. DUSENBURY at the Textile Research Institute Annual Meeting, New York City, March 17.

Some Aspects of Fatigue in Man-made Fibers, presented by W. JAMES LYONS at the Textile Research Institute Annual Meeting, New York City, March 17.

The Resin Treatment of Cotton Fibers, presented by L. REBENFELD at the Textile Research Institute Annual Meeting, New York City, March 17.

Thermoanalytical Studies of Textile Materials, presented by ROBERT F. SCHWENKER, JR. at the Textile Research Institute Annual Meeting, New York City, March 17.

Evolutionary Operations, presented by JOHN C. WHITWELL at the Spring Lecture Series of the New Jersey Section of the American Institute of Chemical Engineers, Bound Brook, New Jersey, April 13.

New Synthetic Fibers and Fibers of the Future, presented by J. H. DILLON before the Princeton Area Science Education Committee, Princeton, New Jersey, April 19.

The Influence of Fiber Properties on Manufacturing Performance, presented by L. REBENFELD at the Cotton Marketing Conference Research Clinic of the National Cotton Council of America, Memphis, Tennessee, May 15.

Requirements for a Graduate Education in Textiles, presented by L. REBENFELD at the Textile Faculty Seminar of the National Council for Textile Education, Clemson, South Carolina, June 6.

Thermoanalytical Methods, presented by ROBERT F. SCHWENKER, JR. at the Seminar Program, Philip Morris Research Center, Richmond, Virginia, June 20.

Frictional and Surface Properties of Fibers, presented by STANLEY C. SCHEIER at a special program for the Textile Division, Department of Mechanical Engineering, Massachusetts Institute of Technology, June 21.

Applications of Modern Thermoanalytical Techniques in Studies of Textile Materials, presented by ROBERT F. SCHWENKER, JR. at the Gordon Research Conference on Textiles, New London, New Hampshire, July 10.

A Theoretical and Experimental Study of Polymer Dyeing, presented by THOMAS J. COCHRANE, JR. at the Gordon Research Conference on Textiles, New London, New Hampshire, July 12.

Organization and Operation of an Industry Research Institute, presented by J. H. DILLON at the Second Naval Research Reserve Seminar on Research Planning and Management, Princeton, New Jersey, August 30.

Effect of Fiber Tension in the Resin Treatment of Cottons, presented by L. REBENFELD at the Fall Meeting of The Fiber Society, West Point, New York, October 12.

A Multivariable Investigation of the Spinning of a Mixed Polymer System, presented by JOHN C. WHITWELL and GRAHAM K. MORBEY at the Fall Meeting of The Fiber Society, West Point, New York, October 13.

Effect of Fiber Properties on Certain Textile Processes, presented by L. REBENFELD at a meeting of the Textile Engineering Division, American Society of Mechanical Engineers, Cambridge, Massachusetts, November 2.

DOCTORAL DISSERTATIONS

A Theoretical and Experimental Study of Polymer Dyeing, THOMAS J. COCHRANE, JR., Department of Chemical Engineering, Princeton University, April, 1961. Advisor: Professor Richard H. Wilhelm.

Volume Changes Accompanying Acid-Base Reactions of Keratin Fibers, DONALD D. KASARDA, Department of Chemistry, Princeton University, August, 1961. Advisor: Professor Walter J. Kauzmann.

MASTER'S THESIS

Nonwoven Fabrics: Preparation of Samples and Experimental Design for a Multivariable Experiment, GERALD H. BJORGE, Department of Chemical Engineering, Princeton University, September, 1961. Advisor: Professor John C. Whitwell.

PATENTS

Flame Resistant Cellulose Derivatives, EUGENE PACSU and ROBERT F. SCHWENKER, JR., United States Patent 2,990,232 (June 27).

After-Glow Suppressing Cellulose Derivatives, EUGENE PACSU and ROBERT F. SCHWENKER, JR., United States Patent 2,990,233 (June 27).

Flame Resistant Cellulose Derivatives, EUGENE PACSU and ROBERT F. SCHWENKER, JR., British Patent 873555 (November 15).

Improvements in the Production of Cellulose Derivatives, EUGENE PACSU and ROBERT F. SCHWENKER, JR., British Patent 873556 (November 15).

TRI SEMINARS

Chemical Reactions of Cellulose and Cellulose Derivatives—R. F. SCHWENKER, JR., Textile Research Institute, January 12.

The Behavior of Model Particles in Laminar Shear Flow—S. G. MASON, Pulp and Paper Research Institute of Canada, February 23.

Equilibrium between Monomer and Polymer—PROF. A. V. TOBOLSKY, Princeton University and Textile Research Institute, March 9.

Properties of Viscose Rayon as a Function of Swelling and Temperature—R. A. GILL, Rohm & Haas Company, March 30.

Fiber Structure as Revealed by Sonic Techniques—W. W. MOSELEY, JR., E. I. du Pont de Nemours & Co., April 13.

Polymer Characterization by Differential Thermal Analysis—R. C. WINCKLHOFER, Allied Chemical Corporation, May 4.

Recent Developments in the Theory of Dyeing—W. H. FOSTER, JR., American Cyanamid Company, May 18.

Path to Great Discoveries in Dyestuff Chemistry—PROF. WALTER JENNY, University of Berne and Ciba Limited, Switzerland, September 21.

Effect of Fiber Structure on Dyeability with Disperse Dyes—B. S. SPRAGUE and R. W. SINGLETON, Celanese Corp. of America, October 26.

Surface Properties of Fibers—STANLEY C. SCHEIER, Textile Research Institute, November 16.

Effect of Humidity on Crease Recovery of Modified Cellulosic Fabrics—R. A. GILL and R. O. STEELE, Rohm & Haas Company, November 30.

Optical Rotatory Dispersion Studies of Soluble Wool Proteins—HENRY W. SAFFER, Textile Research Institute, December 14.

STAFF PROFESSIONAL ACTIVITIES

JOHN H. DILLON, President, The Fiber Society; Member, Board of Trustees, The Philadelphia College of Textiles and Science; Editorial Board, Journal of Applied Polymer Science; Member, Advisory Panel to the Organic and Fibrous Materials Division of the National Bureau of Standards, National Academy of Sciences; Member, American Panel, The Textile Institute.

W. JAMES LYONS, Member, Executive Committee, and Secretary-Treasurer, Division of High-Polymer Physics, American Physical Society.

LUDWIG REBENFELD, Member, Awards Committee, The Fiber Society; Member, Committee on Educational Cooperation, The Fiber Society.

ROBERT F. SCHWENKER, JR., Secretary-Treasurer, Princeton Area Science Education Committee; Participant, Professor Visitation Program, The Chemstrand Corporation.

PROGRAM—1961 ANNUAL MEETING

THURSDAY AND FRIDAY, MARCH 16 AND 17, 1961

Opening Remarks, GEORGE H. HOTTE, Director, Fiber Marketing Department, National Aniline Division, Allied Chemical Corporation, and Chairman, TRI 31st Annual Meeting.

An Automatic Doffing System for Spinning Frames and Twisters, ROBERT W. MCCULLOUGH, Product Manager, Deering Milliken Research Corporation

Problematics in Reactive Dyeing, JACQUES E. WEGMANN, Ciba, Ltd., Basle. Currently, Applications Laboratories, Toms River Chemical Corporation

Some New Interpretations of the Tire Cord Fatigue Phenomenon, W. G. KLEIN, W. J. HAMBURGER, and M. M. PLATT, Fabric Research Laboratories, Inc. Presented by W. G. KLEIN

Research Trends in the Pulp and Paper Industry, LINCOLN R. THIESMEYER, President, Pulp and Paper Research Institute of Canada

Effect of Radial Heterogeneity on Fiber Properties, R. W. SINGLETON and M. A. SIEMINSKI. Presented by R. W. SINGLETON, Group Leader in Charge of Evaluation Research, Summit Research Laboratories, Celanese Corporation of America

Polypropylene Textile Fibers, GILMAN S. HOOPER, Director of Research and Development, Fiber Development Department, Hercules Powder Company

State of the Institute, J. H. DILLON, President, Textile Research Institute

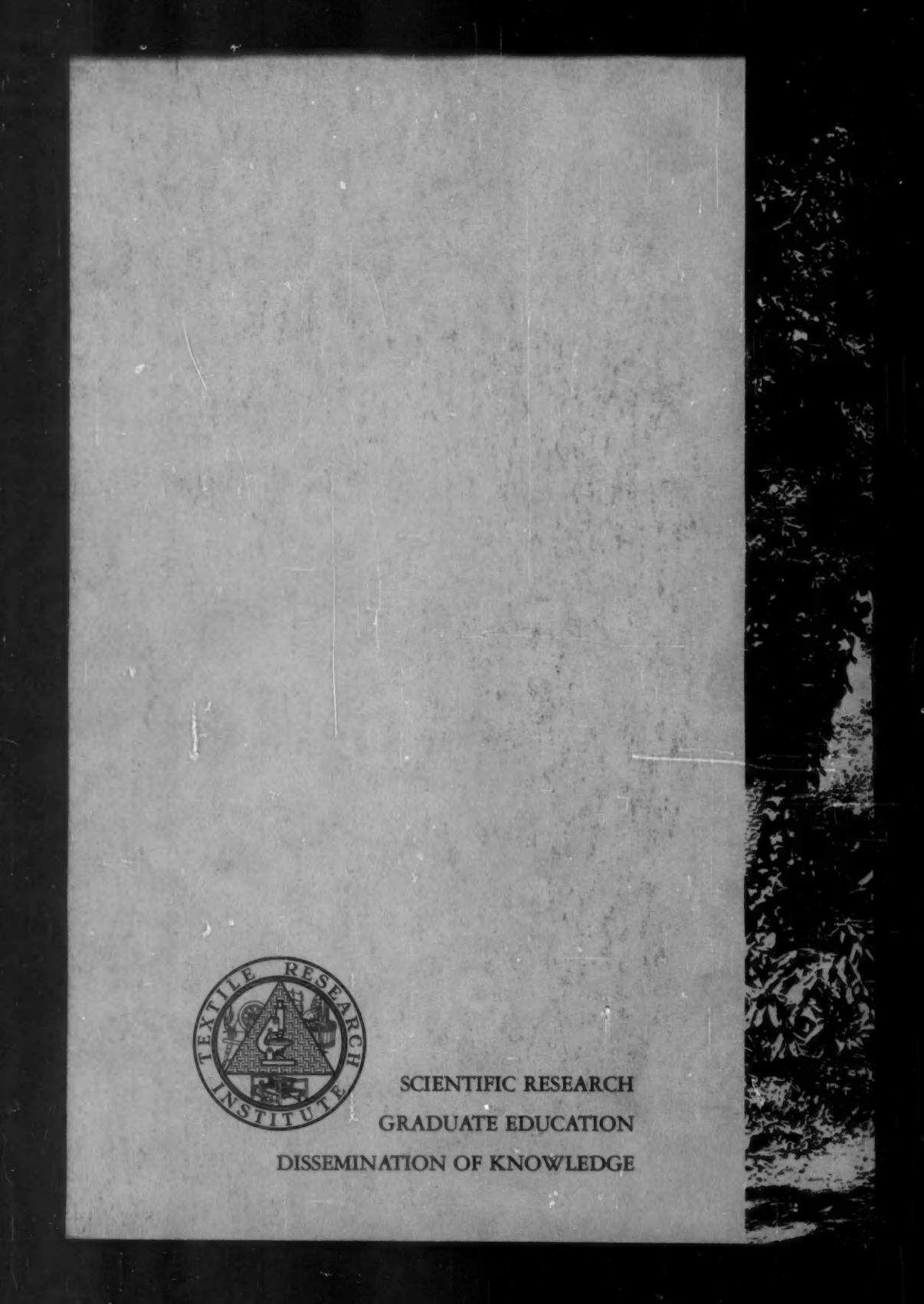
Current TRI Research: Studies of Wool Fibers Relating to Minimum Care Applications, J. H. DUSENBURY, Associate Research Director

Some Aspects of Fatigue in Man-Made Fibers, W. J. LYONS, Associate Research Director

Effects of Fiber Tension in the Resin Treatment of Cottons, L. REBENFELD, Associate Research Director

Thermoanalytical Studies of Textile Materials, R. F. SCHWENKER, JR., Associate Research Director

What About These Soaring Sixties? DEXTER MERRIAM KEEZER, Economic Advisor, McGraw-Hill Publishing Company, Inc.



SCIENTIFIC RESEARCH

GRADUATE EDUCATION

DISSEMINATION OF KNOWLEDGE